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Potential Benefits of Wearable Technologies on Preschooler Outdoor Safety

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AALTO UNIVERSITY SCHOOL OF SCIENCE | ABSTRACT OF THE MASTER'S THESIS

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This research takes interest in the dangers surrounding preschoolers' excursions outdoors in Finland and aims at proving that wearable technologies have potential to improve the situation.

In a first step, the situation regarding traffic accidents is analyzed from a general standpoint and then with a specific focus on children. It stems that Finland's situation has room for improvement – mainly because other countries in similar conditions and development states achieve significantly better results. Furthermore, it is clear that children are especially vulnerable to accidents because of their physiological and cognitive characteristics as well as harsh weather conditions during a large part of the year.

Wearable technologies are then introduced, both from a historical and practical point of view, highlighting the ever-growing potential they hold for children safety, and presenting previous studies with similar interests.

This theoretical analysis is then used as a basis for practical ideation to develop concepts improving children's safety thanks to wearable devices. Combining interviews of preschool teachers and an ideation workshop, a number of concepts are developed and refined, offering leads for practical implementation of safer solutions than the current ones.

In a next step, these concepts are stripped down to their very core in order to design a functional proof of concept as simple as possible. A prototyping phase was then carried out based on this design, yielding a working device aiming at creating a fun experience for the children while making them more visible to passing drivers and preventing any unexpected behavior. This prototype validated the core concepts and proved the potential of wearable technologies in the field of children safety, as it addressed several of the main challenges currently responsible for the dangerous situations and their deadly consequences, such as the lack of attention from children or the lack of visibility for drivers.

In conclusion, this prototype enabled to prove that wearable technologies could definitely improve the safety of preschoolers in Finland, and the concepts developed along this study offer several leads as to how to practically implement efficient new solutions.

Keywords: Children, Finland, safety, traffic accidents, wearable technologies, OJAS	Publishing language: English

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I.1.PURPOSE OF THE TESTING

In most developed countries such as Finland, children deaths or injuries have reached all-time lows over the past decades, thanks to huge improvements in many different fields – like healthcare or safety technologies (Viner R. M. et al., 2011). However, there are still progresses to be made, as many accidents could be prevented each year and numerous lives saved using various social or technological tools (MacKay M. et al., 2012).

The present research aims to find where and how some of these improvements could be achieved to continue lowering children endangerment. More specifically, this thesis will focus on preschooler safety in Finland.

Indeed, even though Finland presents one of the lowest child mortality in the world, it is far from achieving the best results. When compared to Sweden for example, Finland's situation is significantly worse (UNICEF, 2001) (WHO, 2014). However, both countries have to face many of the same challenges such as frequent bad weather, low outdoor visibility and extremely short daytime during long winters, along with a comparable development level. Weather and visibility conditions are important factors for children's safety since in European countries, accidents and specifically traffics accidents now accounts for a large part of deaths in children under 10 years old, and are directly linked to these factors (Remes H. et al., 2010) (Brandstaetter C. et al., 2010).

This research will focus on developing ideas and implementing a prototype for preschooler children aiming at improving outdoors safety in context of traffic accidents. The main interest will be to explore concepts using wearable technologies as part of a solution for these challenges. In fact, the ever-growing availability and potential of wearable technologies is pushing them towards becoming a core part of our daily lives (IHS Electronics & Media, 2013). Specifically in regards of children safety, they could probably achieve major improvements by facilitating, speeding up or automating the monitoring processes of children in risky situations among other things. This thesis will thus try to assess if the belief that wearable technology could greatly decrease children deaths and injuries in Finland is founded or not. This will be achieved through thorough investigation of existing theory and of the current situation, leading to the development of a prototype enabling actual measurement of the improvements over the existing solutions.

I.2.RELEVENCE OF THE RESEARCH

I.2.a.CHILDREN AND TRAFFIC ACCIDENTS

This research stems from a simple yet crucial realization that even in a developed country like Finland – among the most developed and with the highest life standards in the world (Porter M. E. et al., 2014) – traffic accidents are still a deadly reality and claim many lives every year. It is one of the major causes of deaths for all age groups in developed countries (Brandstaetter C. et al., 2010), and yet, a lot could be done to decrease accidental deaths. Indeed, research estimated that if appropriate strategies known to be effective were implemented globally in all of European countries, up to 90% of injuries could be prevented (MacKay M. et al., 2012). Such strategies include for example education towards traffic safety and behavior, preventive devices, and more pedestrian-friendly cities.

Indeed, cities are still the most dangerous place for pedestrian regarding traffic accidents, with a much higher proportion of pedestrian deaths in urban areas than in the countryside in the OECD (Papadimitriou E. et al., 2006).

Moreover, children are especially vulnerable to this danger, and traffic accidents represent an even higher part of deaths in this age group (Whitebread D. et al., 2000). Unintentional injuries have indeed replaced infectious diseases as the most serious health problem of children in the industrialized world (Abboud Dal Santo J. et al., 2004). Children can in fact have an unpredictable behavior that can lead to situations unusual to drivers and thus dangerous. For that reason, it is necessary to create settings that draw attention to the presence of children (Tutert, Else, 2004).

However, despite this well-recognized and documented problem, or the fact that many solutions for traffic accident prevention have been successfully tried, these proposed solutions are rarely taking into account the specific needs of children, may it be their smaller physical size or their limited cognitive capacities. They mainly target the general setting of the environment for example by reducing the vehicles speed or trying to separate in time pedestrians and vehicles (Retting R. A. et al., 2003). Considering how children can be disobedient of rules or even unaware of the risks they put themselves in, this kind of solutions are probably not the most effective as they rely on conscious realization of the danger.

I.2.b.CHILDREN AND WEARABLE TECHNOLOGIES

This thesis aims at proving that on the other hand, wearable technologies, can provide the kind of solution appropriate for children, since technology embedded in the children clothes could provide clever behavior to protect children without need for them to explicitly know about it.

Wearable technologies are becoming increasingly available, powerful and cheap (IHS Electronics & Media, 2013) which makes it an ideal time for the present research to be carried out.

Wearable technologies have been already been researched in the context of their potential with children, for example to study their behavior or understand how they interact in their daily lives, but it seems that most of the interest stayed purely on an academic level. (Williams M. et al., 2005) (Olguín D., 2007)

This research aims at implementing a real prototype using wearable technologies and then rely on its inherent capacities to embed smart features. This way, the children will have the system on them at all time in order to struggle against the pitfalls of the current situation that create dangerous settings. As this study will demonstrate later on, the major aspect will be to provide motivation for the children to stay focused and safe, as well as solve the specific settings of Finland that make it an even more dangerous place for pedestrian, such as the long winter with reduced visibility (Tyrrell R. A. et al., 2004). Then, it would become possible to rely less on the children unpredictable behavior and limited attention span for traffic safety.

All these facts combined highlight the potential of such a device, and thus the need for this research to be carried out.

I.3.GOAL AND RESEARCH QUESTIONS

As mentioned previously, this research ultimately tries to assess the future of wearable technology in children safety, and specifically in the context of outdoor excursions in groups, where a limited number of adult supervisors are in charge of a larger group of children, who are thus even less focused than usual (Veysel Dogan Akgul, 2008, p. 22), creating potentially deadly situations.

The main research question that this thesis tries to answer is thus: "how can wearable technologies be used to improve preschooler children safety in outdoors situations in Finland?"

The first key point to be investigated in the scope of this research is then: what are the current challenges of preschoolers' safety in regards of accident protection, and specifically traffic accidents? How can wearable technologies be used to solve these challenges? These are very complex questions, and thus the research will focus only on some specific solutions in order to be able to build a proof-of-concept prototyping.

Thus, the second part of the research will try to answer the following questions: what are the key points to take into accounts while designing solutions to make them as efficient and user-friendly as possible? How to create a potential solution to these challenges integrating wearable technologies?

Finally, a prototype will be built from the design in order to validate the hypothesis and design choices made throughout the thesis and discover potential technical shortcomings.

I.4 STRUCTURE OF THE THESIS

This thesis is divided in five chapters, representing as closely as possible the research process carried out during the study.

In this first chapter, the thesis was presented, first by detailing the topic and then by presenting the reasons justifying its relevancy. Finally, the final aim of the research was explained by explicating the questions that the thesis will try to answer.

The second chapter dives right into the given problematic, as the existing situation is analyzed through official statistics and publications. This gives a better grasp of the problem at hand and yields leads for explaining the reasons behind it. Furthermore, wearable technologies are also explored from a theoretical standpoint, in order to present their status and why they are believed to be relevant for the problem at hand.

From there on, the third chapter focuses on the research methods that are used for moving forward from the uncovered theoretical data to practical solutions and findings. Then, a discussion is carried out to present how using these methods make for relevant results in this research.

The fourth chapter presents the contents of the findings, including the conclusions from the interviews and the prototyping outcome.

Finally, a discussion of these findings and their meaning is taken in the fifth chapter, explicating the thesis results and presenting how the defined goals were achieved. To conclude, the next possible steps that can be taken to carry this research forward are detailed.

II.BACKGROUND OF THE STUDY

II.1.TRAFFIC ACCIDENTS

The following paragraphs provide an overall quantitative look at the problem of traffic accidents, with a focus on pedestrians and children, thanks to official statistics from several organizations that keep track of this global phenomenon. This enables the research to start on solid factual grounds before looking thoroughly at literature and helps in the understanding process of this research's context.

II.1.a.FINLAND'S SITUATION

Europe, and more specifically Finland is the main focus in this research, which seeks to understand how is the current situation in order to assess where and how action is required.

In Europe, children traffic deaths have reached an all time low over the past years, and the death toll is still decreasing, as can be seen on figure 1 (Transport injuries).

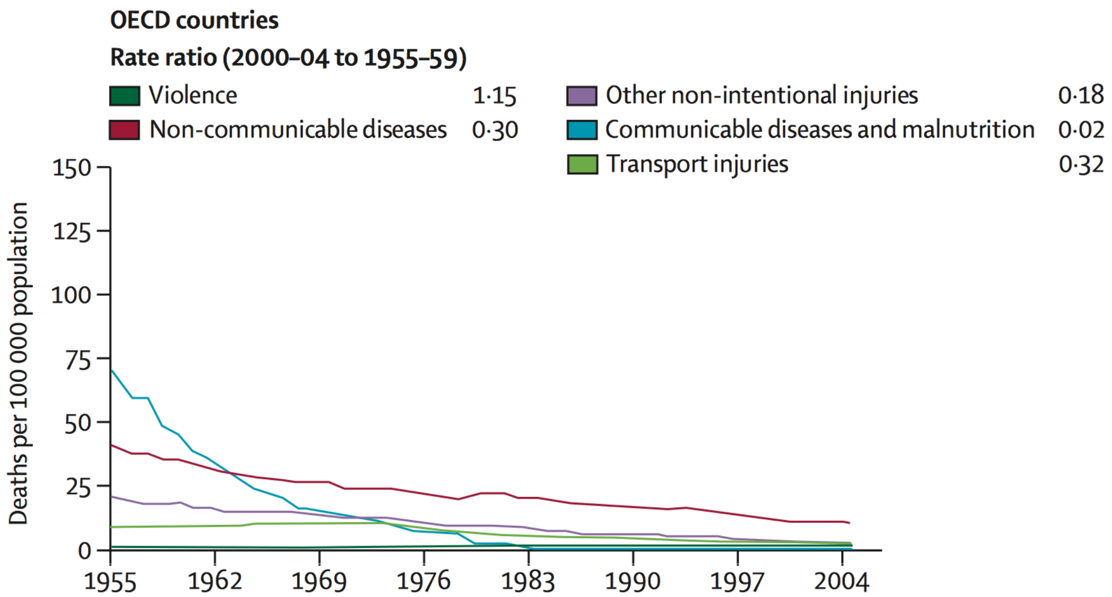

Figure 1 – Causes of death in children aged 1–9 years from 1955 to 2004 (Viner R. M. et al., 2011, p. 1168)

However, pedestrian fatalities remain one of the most important causes of death in all age groups, as can be seen on figure 2 below.

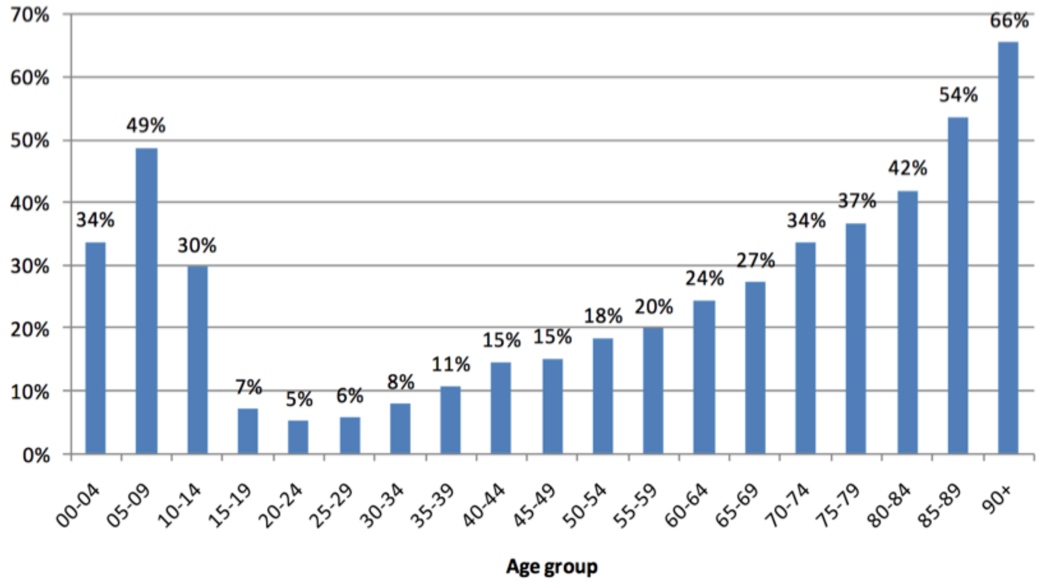

Figure 2 – Pedestrian fatalities as a percentage of all fatalities by age group, EU-16, 2008 (Brandstaetter C. et al., 2010, p. 7)

This graph already hints at a problematic situation for children, and specifically for children aged between 5 and 10, but this will be detailed in the next section.

Looking at the raw numbers, it is clear that European countries and especially Finland have one of the lowest fatality rate due to traffic in the world, but Finland is still far from achieving the best results. Even in among other Northern countries, the death toll is lower than in Finland, which tends to corroborate with this research hypothesis that a lot can still be done to improve the situation. In fact, in 2008, Finland had 10 pedestrian deaths per million inhabitants, when Sweden only had 5 (Brandstaetter C. et al., 2010). The main reason why has lower casualties than Finland is the implementation of a zero-casualty policy (pedestrian zones around schools, etc.). Although this could be a key to reduce pedestrian fatalities in Finland, this will not be studied here, because it does not belong to the scope of this study.

Northern countries are especially affected by traffic accidents, because of their long winter during which the nights are longer than in most other countries. Statistics show that in Europe, a staggering 48% of traffic related deaths happen during the dark, even though pedestrians' presence is presumably much lower at night than during the day (Brandstaetter C. et al., 2010). This clearly underlines the responsibility of darkness in regard of traffic accidents.

Moreover, in Finland in 2010, 36% of deaths happened during a three-month timeframe – between October and December – when the daytime was continuously decreasing. This is one more signal that this research should focus on low-visibility settings, considering that they seem to represent the most dangerous situations.

Finally, another interesting fact that the statistics analysis raised is the fact that in the matter of pedestrian protection, urban areas are much more of a concern, with a pedestrian death rate significantly higher than outside of cities, as illustrated by figure 3. It can be seen that, although most of all fatalities occur outside urban areas, the majority (around 70-80%) of reported pedestrian fatalities happened in urban areas (Papadimitriou E. et al., 2006).

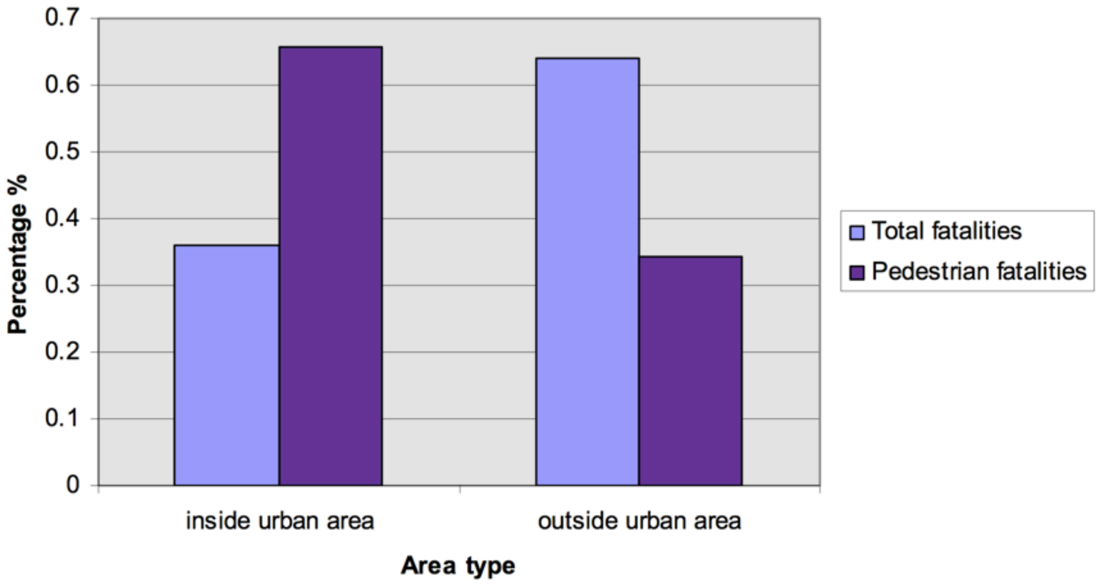

Figure 3 – Percentage of pedestrian fatalities - OECD 1996-2006 (Papadimitriou E. et al., 2006, p. 6)

II.1.b.FOCUS ON CHILDREN

A major point that comes out of various reports is the over exposure of children to traffic accidents: more than in any other age groups, traffic accidents are responsible for most of children's death in developed countries.

Statistics have demonstrated that children in 5-9 year range are particularly over represented in pedestrian accidents, suffering up to four times the casualty rate of adults (Whitebread D. et al., 2000).

Furthermore, in Europe, more children aged 5-19 years die of injuries than all other causes combined (MacKay M. et al., 2012).

Finally, it stems from the statistics that Finland could also significantly lower its number of children deaths caused by traffic. Indeed, in 2008, the child pedestrian fatalities (between age 0 and 15) as a percentage of all pedestrian fatalities was as high as 6% in Finland, when during the same year, Sweden rate was only of 2%. On top of that, the EU-23 average lied at 5%, putting Finland behind it. Moreover, Finland had a 4.2 deaths per 100000 children per year, which can be compared to Sweden's 2.5 and Norway's 2.9 (UNICEF, 2001). Once again, it seems that Finland has a lot of room for improvement in the matter of children safety regarding traffic, as even in other Northern countries facing the same challenges and with similar development levels, the death toll is notably lower.

In conclusion, there is no doubt left that traffic accidents killing pedestrians – and especially those involving children – are a major problem nowadays, and even if actions are being taken to improve the situation, much has yet to be done. This research is trying to take a new angle on the problem by adding the wearable technology component as a basis for a solution.

The next section takes a look at literature to try and understand the reasons for such a situation, and explain why children are so vulnerable to traffic accidents in general.

II.2.LITTERATURE REVIEW: FACTORS INFLUENCING ACCIDENTS AND POTENTIAL FOR WEARABLE TECHNOLOGY

It has been shown from the statistics analysis that there is a real challenge with pedestrian and traffic, resulting in numerous deaths every year. Two key points have been highlighted in the previous part: most of these deadly accidents happen during times when visibility is reduced –like winter-time for example – and children are especially affected by this phenomenon.

The next part takes a look at existing literature to try and understand the reasons for this situation.

II.2.a.DARKNESS RELATED DANGER

Dark times represent a fairly significant portion of pedestrian deaths related to traffic accidents, and this in spite of a decreased frequentation of roads by cars and pedestrians during this period. It has indeed been stated in 2004 by Tyrrell R. A. et al. that "despite the presumed decrease in pedestrian exposure at night, 65% of all fatal vehicle-pedestrian collisions […] occurred at night.". Moreover, estimates suggest that pedestrians may be 3 to 6.75 times more vulnerable in the dark than in daylight when other factors are held constant (Sullivan, J. M. et al., 2002) – mainly eliminating accidents due to alcohol consumption or tiredness, two other main sources of traffic accidents.

It is crucial to understand the reasons for this in order to be able to prevent the consequences.

After looking at literature, it stems that the reason behind the higher risk doesn't solely lie in the obvious explanation that drivers need to be closer to pedestrians before noticing them than during the day, and thus have less reaction time to avoid them. The literature reviewed was focusing on pedestrian behavior mainly, and some other factors need to be taken into account.

A first piece of answer lies in the general behavior of pedestrians when interacting with traffic. In fact, it seems that pedestrians do not pose as much conformity to traffic regulations as drivers do (Veysel Dogan Akgul, 2008). In more details, it has been observed that while laws are strictly followed by a vast majority of drivers during their trips thanks to a proper enforcement of the regulation for motorized vehicles, the same doesn't apply to pedestrians.

For example, they tend to cross traffic relying on their own observations, optimizing their trajectory to save time instead of following the actual rules. A pattern has indeed been observed, when pedestrians cross diagonally at midblock, following closely behind the last vehicle that passes them, […] probably increasing exposure to traffic because of the additional time spent in the roadway (Schieber R. A., 1996).

This kind of behavior is especially dangerous during dark times, when visibility is reduced along with the observation capabilities of the pedestrians. In fact, it has also been established that darkness alters pedestrians' perceptions pushing them to wrong estimates. As a consequence, they are more likely to unconsciously put themselves in danger.

One of the most important proofs of this observation is the fact that pedestrians have a tendency to overestimate their conspicuity to approaching drivers at night [...] by a factor of 1.8x. (Tyrrell R. A. et al., 2004). The experiment required pedestrians in dark conditions to assess when they were certain that an approaching vehicle had spotted them. By largely over-estimating this fact, pedestrians often have a delusive feeling of secure situations and expect drivers to react in regard to their own actions while drivers haven't even acknowledged their presence yet.

These two facts combined constitute a good explanation for the dangerousness of low-visibility settings in regard of traffic accidents. It has indeed just been underlined that pedestrians tend to rely on their own observations instead of the official laws while those very estimations are usually biased in the dark.

II.2.b.CHILDREN SAFETY

As the main focus of this research lies within preschoolers' safety, the next step of the analysis takes a deeper look at the reasons why children especially represent such a big share of the traffic accident death toll.

Multiple research have been studying this very critical phenomenon, and a good summary of the reasons for it is that, when asked to deal safely with traffic, children are likely to be exposed to threats that exceed their cognitive, developmental, behavioral, physical and sensory abilities (Schieber R. A., 1996). Basically, children are different from adults on many levels and it makes their dealing with the situation much harder. We can divide these differences in two big categories, physical aspects and mental aspects.

II.2.b.i.CAUSES DUE TO PHYSICAL ASPECTS

First of all, the physical characteristics of children are cause for a lot of dangers related to traffic accidents. In his 2008 research report, Veysel Dogan Akgul lists most of these causes, which are detailed in the following paragraphs.

The first and most obvious one is that the children' smaller physical size makes them less visible to drivers. Once again, drivers rely a lot on their habits and experience when driving, and thus can be surprised by the presence of children, less usual than that of grown-up pedestrians. That being said, the smaller size of children mainly makes them harder to spot in an urban environment with multiple obstacles lowering the visibility, like parked cars for example. As presented in the previous part of this chapter, lack of visibility is a leading cause of accidents, and it is especially affecting children even in broad daylight.

The parked cars example leads to the second reason linked to the physical characteristics of children: the environment is utterly not adapted to them. Parked cars hide them from drivers, but they mainly prevent children from being able to see any traffic before entering it. They are thus forced to put themselves in more dangerous situations than adults. Moreover, pedestrian protection is enforced through laws, which most adults have come to know and understand. But children don't have the necessary experience with traffic to know the meaning of the rules they are supposed to follow. Traffic lights are a good example, and such codes have to be acquired before they can be truly efficient.

Finally, children being smaller mean that they move more slowly than adults. From there some configurations become tricky challenges for children, like crossing wide roads. This particular example was studied by analyzing children crossing patterns: a majority of them relied on traffic islands – plot of curbs used to divide wide roads in several smaller sections – when possible whereas adults tended to avoid them (Schieber R. A., 1996). This proves that children strive to walk as small distances as possible while dealing with traffic. However, this conclusion assumes that children are indeed able to find out where the safest crossing point lies, and thus puts into focus the reason linked to the cognitive limitation of children while their mental development is still at an early stage.

II.2.b.ii.CAUSES DUE TO COGNITIVE DEVELOPMENT

Jean Piaget developed a theory regarding children development, and stated that children usually go through the same development steps in the early years of their lives, experiencing several phases during which very specific cognitive capabilities are developed (Bringuier J. C., 1980) (Duval S. et al., 2007). Then, it has been highlighted in previous parts of this research that the age group most affected by lethal traffic accidents was during the first years of school, around 5 years old, and the literature review thus focused primarily on this development stage.

At this age, children are right in their second stage of development, between 1.5 and 7 years old: it is the step of fantasy and mobility (Schieber R. A., 1996). Fantasy is the fact that children develop the capacity to imagine things and situation within their mind, and at this stage, it can completely make them lose touch of reality. They are able to totally escape their direct environment relying only on their creativity. On top of that, they integrate their environment in their fantasy, creating dangerous possibilities, like a child considering moving cars around him as part of his fantasy that he could control. Then, the stage of mobility is reached when children learn how to move on their own, and finally don't require any external help to do so. Putting this in relation with traffic, it can lead to deadly consequences. Children can be focusing on their own mind scheme, and move through space as a part of their "games", without realizing the real danger they put themselves into.

Furthermore, children in this age group often believe that they are at the center of the world and since they can see themselves, they can be seen by everyone else (Schieber R. A., 1996). This limitation of their cognitive capacities makes it even more difficult for them to understand that drivers can not see them at all times and that they need to protect themselves from dangerous situations, especially considering that they don't necessarily pay real attention to their surroundings.

The lack of attention is actually a consequence of the fantasy capability, but can also be amplified when children are gathered in groups. This has been noticed by the Child Accident Prevention Foundation of Australia in 2006, and puts even more pressure on school excursions, when interactions between children tend to push their focus even more off of their surroundings and leaves them more vulnerable.

The third key point of this analysis is that children lack the capacity to actually decide if a situation is safe or not when faced with it. Schieber R. A. for example states that a 5 year-old child requires about twice as long to reach a pedestrian decision than an adult. In other words, the lack of experience and their smaller understanding makes this kind of decision longer for children. However, traffic interaction requires quick reactions, as a situation can balance between safe and unsafe in a matter of seconds.

On top of that, it has been established that a preschool child has no ability to recognize a vehicle in motion and run away (Schieber R. A. et al., 2002) when need be. This is a direct consequence of the lack of cognitive skills, as these decisions involve computation above the reach of most children this age as well as a strong requirement for quick reaction.

Another example was enunciated by Grayson in 1975, when in 31% of observed cases, children faced with a traffic decision had 'looked but failed to see' the hitting vehicle (Tapiro et al., 2014). This means that when required to solve these complex situations, children relying solely on their own capabilities will often conclude in the wrong direction, leading them to potential accidents setups. For example, in Australia, the Office of Road Safety (FORS) observed that on the 31 pedestrian deaths concerning the 5 to 12 age group in 1992, 28 incidents could be analyzed with enough data and of those, 24 incidents were caused only by child failure. (Veysel Dogan Akgul, 2008).

This analysis highlights clearly that children do not always act or react in traffic situations in ways adults would expect, and that it is thus the responsibility of adults and of the road controlling authorities to create infrastructure designs that draw attention to the presence of children (Tutert, Else, 2004) as well as provide help and implement process specifically designed for children safety.

To conclude after uncovering and analyzing the main reasons why children are affected so importantly by traffic accidents, the most notable outcome of this literature review was that a very large majority of the accidents involving child deaths could be avoided, highlighting the potential for improvement that this research seeks to achieve. More precisely, it is estimated that 90% of children deaths by injuries in Europe could be avoided with proper application of measure. (MacKay M. et al., 2012). As stated in the previous chapter of this study, collisions between vehicles and pedestrians are a leading cause of child deaths in developed countries, but this is evidence toward thinking that it can be highly improved. An example is demonstrated in another study, which proved that simply providing free visibility aids and an educational booklet on road safety significantly increases use of visibility aids in the winter (Mulvaney C. A. et al., 2006). In other words, the current problem doesn't necessary lie in inefficient solutions, but in a lack thereof, or at least a difficulty to get access to better protection or an unawareness of the potential improvements. Thus, simply providing prevention devices on a more generalized scale would lead to an increase of their use and to an overall safer situation.

These points were a very important statement for this research, giving proof that its aim of significantly lowering accidental deaths among preschoolers is not a utopia. The next step was then to find an efficient means to implement a solution with an ease of use and access that would make its global adoption possible.

II.2.c.WEARABLE TECHNOLOGY: PRESENTATION AND POTENTIAL

This first part of the literature review aimed at getting a better grasp on the reasons behind the traffic accident situation and its deadly consequences.

This second part takes a look at wearable technology: in a first step, a general presentation of wearable technology is given, before highlighting why it is perceived as a potential solution for the studied challenge. Finally, some of the most relevant existing uses of wearable technology found in literature are detailed in order to establish what has already been accomplished with this emerging technology.

II.2.c.i.WHAT IS WEARABLE TECHNOLOGY?

The term "wearable device" refers to electronic technologies or computers that are incorporated into items of clothing and accessories that can comfortably be worn on the body. (Tehrani K. et al., 2013). The definition has evolved a lot since the emergence of the concept in the 1980s with the first wearable computer (Steve Mann, 1997), but in other words, wearable technology nowadays refers to any electronic device with computational capabilities that can be worn by the user. Despite the first steps of the concept being several decades old, it still hasn't truly emerged in our daily lives because of several challenges that needed to be overcome, detailed in the next section of this chapter.

Figure 4 – Steve Mann wearing the first wearable computer in 1980

source: http://cyborganthropology.com/Steve_Mann

Wearable devices have the inherent advantage to be in proximity to the user at all times, giving them interesting potential in many fields, like healthcare and fitness for example. In fact, by integrating sensors into these worn devices, they can have full-time access to the users surroundings as well as physiological measurements, key points for health monitoring.

Several such devices are already present on the mass consumer markets – like the Nike FuelBand, the Jawbone or the Sports Tracker Heart Rate Monitor – but most are still mainly limited to health applications.

Figure 5 – On the left, the Jawbone. On the right, Sports Tracker Heart Rate Monitor

sources:
http://www.wired.com/wp-content/uploads/blogs/reviews/wp-content/uploads/2012/11/20121130-JAWBONE-UP-2012-011edit.jpg
http://shop.sports-tracker.com/media/catalog/product/cache/1/image/9df78eab33525d08d6e5fb8d27136e95/s/t/st_hr_monitor_smart.jpg

As stated in the article from Tehrani K. et al., wearable technology's "potential uses in various fields continues to grow [and] will very quickly change the technological and cultural landscapes". Indeed, on top of health and fitness, the article also mentions that wearable technologies can influence deeply fields as widely spread as "aging, disabilities, education, transportation, enterprise, finance, gaming and music". This research believes that wearable technology could be also used in the field of children safety, and the next section presents the reason for this belief.

II.2.c.ii. WHY WEARABLE TECHNOLOGIES?

Wearable Technologies are expected to gain huge market share in the next few years, both for business and consumer markets (IHS Electronics & Media 2013) deeply changing our lives and the way we interact with our devices and environment. This is the first reason for this study, as wearable technology is about to take off on a global scale. A generalization of wearables means that users will be more open to wearing – or let their children wear – electronic devices and sensors at all times, as well as make cheaper and more powerful components widely available.

This research only aims at highlighting the potential of wearable technologies in safety for children as a simple proof of concept, but much more powerful uses will be possible in the future thanks to an ever-growing number of other wearable devices providing more and more relevant data. Some examples of these further possibilities are detailed in the last chapter of this research.

At this stage, the point is to understand why wearable technologies are currently taking off, and how does it provide potential to solve the studied problem.

First of all, one of the biggest changes of the last years is that there is now a global always-on Internet access at the individual level. This refers to the fact that most people nowadays have a Smartphone with Internet access available constantly. In fact, Smartphones accounted for 53.6% of worldwide mobile phone sales in 2013, up from 38.9% in 2012 (Gartner, 2014), representing more than half of the world's sales, meaning an even higher percentage for occidental countries like Finland. This is a key driver for wearable technology, as pairing wearable devices with Smartphones enables heavy computation to be offloaded online, as well as a powerful user interface using the phone's touchscreen and a potential for combination of data from a very high number of sources. Miniaturization of new electronic components is another explanation for the coming development of wearable technologies: it is indeed another way of getting more powerful and capable devices seamlessly integrated in clothes.

With both these factors, wearables are now able to provide more sophisticated services in devices aware of their context and worn at all times. In this study's case, it means that wearable can be used to make up for the children's lacking cognitive capabilities or fluctuating attention while keeping the device relatively small and cheap.

Smartphones have been widely available for a few years, so it seems as if wearable devices could have emerged already. However, one of the biggest problems remained the powering of such devices. Indeed, providing an integrated outlet is cumbersome and forces a physical access to the electronics embedded in the piece of clothe, while integrated batteries are still lacking efficiency and can't be miniaturized as required. A recent breakthrough in wireless powering solves this problem. A device called the OJAS has been developed and enables wireless charging for wearable devices. Specifically designed to be seamlessly embedded in fabric, it provides two-way short-range power transmission (Mikkonen J. et al., 2014).

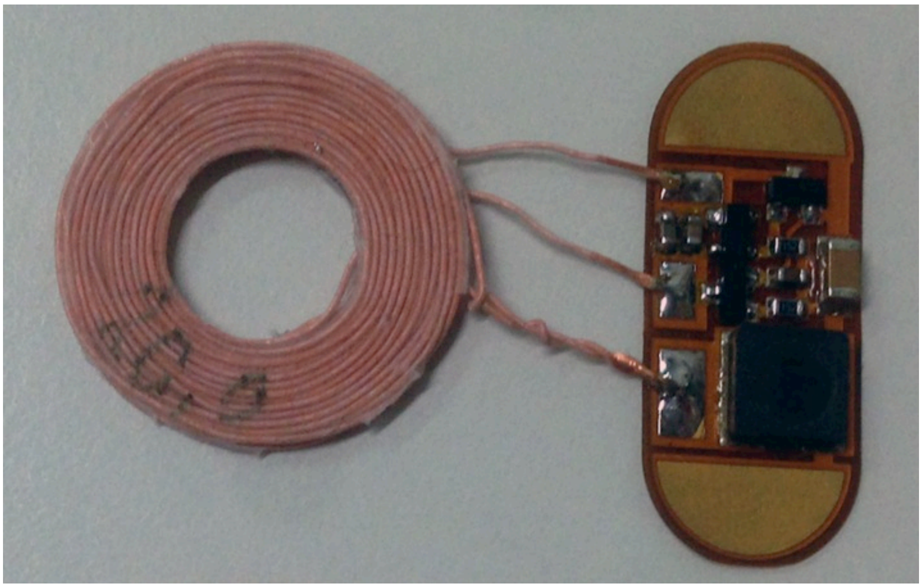

Figure 6 – An OJAS component with its transmitting/receiving coil visible on the left (Mikkonen J. et al., 2014)

This solves two main challenges:

Using the OJAS, there is no more need for a physical external access to the circuitry, which enables devices to be fully embedded and protected, making it much more usable by enabling easy waterproofing for example.

On top of that, wearable devices can be powered wirelessly, which eliminates the need for large and heavy batteries, the only previous option. A single battery can now power a chain of wirelessly connected devices.

This study's prototype will rely on the OJAS' capabilities, as it is perfectly suited for the aim of developing cheap and usable devices as required by a proof of concept. In fact, by dividing the prototype in two parts, a master device wirelessly powering a number of child devices, it is possible to keep the latter ones very simple, thus cheap and user-friendly.

Moreover, providing electricity to clothes enables better solutions to the problem of children safety than the current ones, which have to stay passive. For example, it would be possible to replace or complement reflectors on children's jackets with real lights to make them more visible to drivers, improving the critical situation with this simple addition.

Finally, devices like the Arduino or Raspberry Pi have emerged in the past years, and provided access to easy and extremely cheap interactions to the mass market (Kubitza T. et al., 2014). Those devices consist in small electronic boards with inherent computational power that can be very easily linked to electronic circuits and are completely programmable.

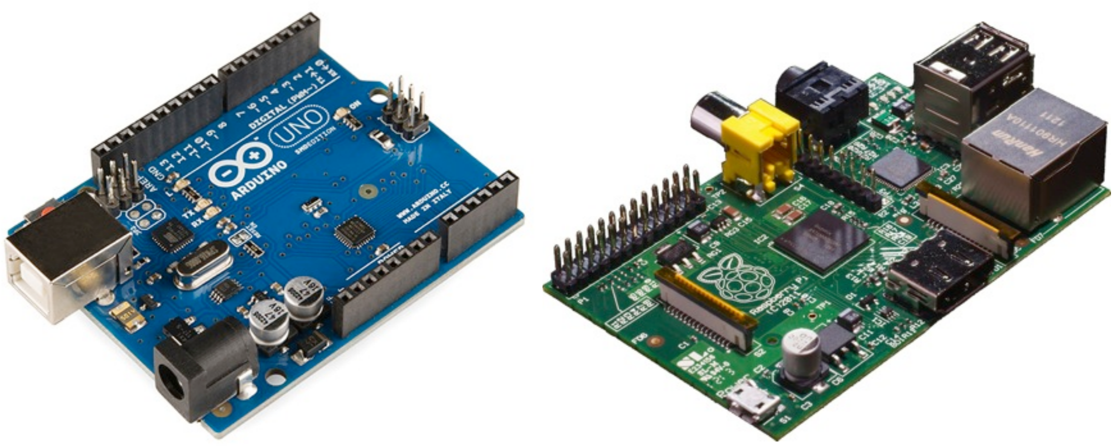

Figure 7 – On the left, an Arduino Uno. On the right, a Raspberry Pi

sources:
http://www.conrad.fr/medias/global/ce/1000_1999/1900/1910/1917/191789_LB_01_FB.EPS_1000.jpg
http://www.journaldugeek.com/files/2014/02/91IakglfbxL._SL1500_.jpg

Using such devices enables very cheap and easy prototyping, thanks to high customization potential and an intended simplicity of use. Furthermore, some dedicated versions of these boards have been designed for wearable technology, adopting form factors specifically to be embedded in clothes. One such example is the Arduino Lilypad: “a fabric-based construction kit that enables novices to design and build their own soft wearables and other textile artifacts. The kit consists of a microcontroller and an assortment of sensors and actuators in stitch-able packages” (Buechley L. et al., 2008).

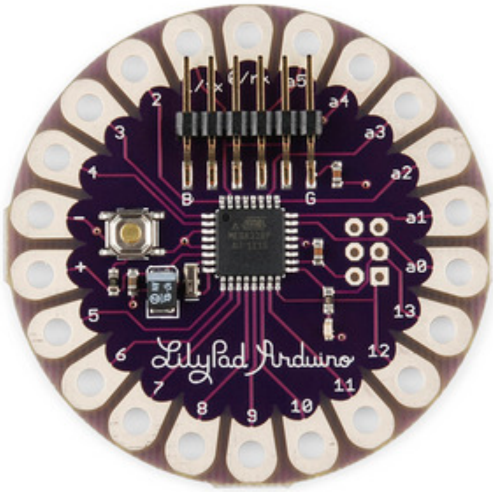

Figure 8 – A Lylipad Arduino (Buechley L. et al., 2008)

All these facts combined make it really clear why wearable technologies are developing faster and faster, and also highlight the potential for the specific case of preschooler safety. The next step will thus be to find interesting and relevant ways to exploit this potential in order to create an effective prototype answering the studied challenges.

An important point to note is that children obviously have specific needs in the matter of wearable technologies – such as different physical body characteristics and mental development stage –which will have implications while designing the prototype and thus needed to be acknowledged (Duval S. et al., 2007).

II.2.c.iii.EXISTING USE OF WEARABLE TECHNOLOGIES

The first research that was studied and found relevant for this thesis’s topic focused on Wearable Electronics and Childcare (Virkki J. et al., 2013). In a kindergarten, personal information from the children was embedded in the children clothes in RFID chips, enabling reliable and quick access to data for the staff on each child: name, class, allergies… Furthermore, this system enabled tracking of the children by registering their arrival and departure times from the facilities. While theoretically, these capabilities were positive for the children and the staff, providing a safer environment and automation of the monitoring of the children, the researchers quickly faced ethical questions and general skepticism from the parents. Indeed, as the world is moving more and more into a digital state, unjustified global surveillance has become a more real threat than ever – as proved by Snowden's revelations on global digital surveillance from the NSA (Greenwald G. et al., 2013) – and consumers are paying more and more attention to their digital presence.

This kind of technology always needs to be implemented with great caution, in order to find a good balance between usability and privacy. In the present context, storing personal information in the children clothes makes a lot of sense as it can be crucial in case of accident or if a child escapes adult supervision. This research will thus investigate how to use the kind of technology presented in the research from Virkki J. et al. while paying special attention to their conclusions regarding privacy infringement.

A second study that provided good insights for the present thesis investigated the potential of Wearable Technologies in human behavior monitoring (Olguín D., 2007). This topic is directly related to the problematic studied here, because as it was established in previous part of the literature review, understanding children's unpredictable behavior could be a key to prevent numerous accidents. In his research, the author provided context-aware wearable devices to a number of employees working in the same real-life organization over a period of one month.

Figure 9 – The wearable sociometric badge developed by Daniel Olguín and provided to the workers (Olguín D., 2007)

This enabled him to demonstrate the potential of wearable technology in behavior monitoring and understanding: through precise measured factors such as duration of interactions or physical activities, he managed to predict actual social factors like the productivity or happiness. Furthermore, the author suggests that this kind of setting could be used with children to monitor their attention span or interactions. This study thus demonstrates in very reliable way that wearable technology can provide the exact type of solution required for children's safety. Indeed, being able to monitor these factors precisely on a group of children would provide a great help to supervising adults by focusing their attention to the child that requires it.

Another study has also investigated potential uses of wearable technologies for children while staying more on an academic level (Duval S. et al., 2007). This enabled the authors to provide a wide spectrum of potential uses, the most relevant of which was again linked to monitoring. Using multiple embedded context-aware sensors, like temperature, humidity or light, they believe that children safety could be greatly improved. For example, these sensors could detect extraordinary situations, and thanks to embedded communication devices, warn the responsible or closest adult of the ongoing event. It is said that such a monitoring could prevent for example drowning. On a higher level, this case is interesting for this thesis's situation because of the demonstration that wearable technologies can be used to offload children responsibilities and self-reliance on nearby adults. In other words, embedding the right capabilities in the devices could make up for the children's lack of experience that is leaving them unaware of surrounding dangers.

A second study took interest in wearable technology as a way of monitoring a user's conditions through sensors. In that case, published in the university of Tampere in Finland, the authors developed smart clothing for the arctic environment (Rantanen J. et al., 2000). The researchers developed a suit integrating advanced electronics in order to monitor the wearer's physiological signals. The monitoring of these internal factors then enables automated response in case of extraordinary measurements that could originate from an accident. In fact, the suit has means to send alert by text message or try and protect the wearer from cold with internal heating. This example shows that in addition to monitoring the direct environment, wearable technologies enable to have constant access to the wearer's condition by monitoring his or her physiological factors. In the case of children accidents, this could mean additional ways of detecting accidents or dangerous situations, as well as potentially launch a response immediately.

Finally, a few projects linking more directly wearable technology and traffic safety were reviewed, the most representative of which is the following smart jacket prototype (Buechley L., 2008).

Figure 10 - Turn signal biking jacket from Leah Buechley, using LEDs and a Lilypad Arduino

This project targeting cyclists uses embedded LEDs to make the rider more visible to cars in a dark environment, and a Lilypad Arduino to control the interactions. In more details, the jacket provides the biker with switches on the wrists, which activates flashing LEDs set on the jacket's back, which are designed to warn nearby cars that the cyclists is about to make a turn in a more visible way than the traditional solutions.

This project is really close to the present thesis in that it is also a proof of concept that wearable technologies can be used to improve safety in traffic-related situations. Furthermore, the very components used in Buechley's project are relevant to this project as well, since they enable fast and simple prototyping making them perfectly adapted to proof of concepts. As such, the turn signal jacket project has been an inspiration while designing the prototype in the present research.

One of the key aspects yielded by this literature review is that even though some existing studies related to wearable technologies are relevant for this thesis, it is safe to affirm that the underlying potential of wearable technologies with a specific focus on children safety and traffic accidents is still mostly unknown. For that reason, this study aims to assess that taking advantage of the latest smart technologies in wearable devices created with respect of children's specific needs could actively help to significantly lower the danger that children often put themselves into while interacting with traffic.

II.3.THE CHALLENGE WE WILL SOLVE

II.3.a. THE ACTORS AT PLAY

Before finally deciding which specific challenge this research needs to focus on, there is an important point left: take a closer look at all the involved actors in the studied context during the sole utilization of the prototype and their respective roles. From there on, it is possible to make a decision about how to solve this problem, based on the previous analysis and by targeting the most relevant actors.

The main actors in the studied context are self-evidently the children. With several factors making them inherently vulnerable to traffic accidents – summarized in the next part of this chapter – they often play a major role in their own accidents. Group traveling can make them even more vulnerable by taking their attention off the environment, or pushing them to unexpected behavior, for example to escape a quarrel with another child.

Another major actor group in the studied situation is composed of the vehicle drivers. Directly involved in the accidents, their role is often due to the fact that they couldn't see the child soon enough or assumed wrongly that their behavior would follow the one of an adult, i.e. trying to protect themselves from danger.

The supervising adults in charge of the children compose a third actor group. In the studied context, each adult is usually in charge of several children at once, required to pay attention to all of them at once, and responsible for each of their own safety. Furthermore, they are also in charge of directing the excursion and interacting with other people during the trip - like public transportation drivers for example – and as such have a constant load on their attention, which might lead to a child escaping their surveillance and an accident.

Finally, the last group is composed of the remainder of people present during the excursion, mainly passing adults. As was reported by a preschool teacher in an interview, they can make the situation even more dangerous by breaking the usual process setup by the teachers. Indeed, when they feel like the teachers are overwhelmed with the number of children, they can try and help, often resulting in a counterproductive result, as they miss the proper information about the normal flow of actions used by the teachers to keep the children safe.

II.3.b.DEFINING THE CONTEXT OF THE SOLUTION

After this literature review that helped to understand the situation as well as potential directions for improving it, there is a need to focus back this study on one of the challenges that was uncovered and design the prototype according to its own specifics.

It was decided that the most relevant targets for the prototype were the children directly, for the following reasons.

First of all, they are the most unreliable and often sole reason for accidents – as highlighted in the previous chapter – and technology can help to compensate for their erratic behavior. By targeting the children it is also possible to help the supervising adults monitoring process, as well as tackle the facts that make them so vulnerable to accidents, such as their lack of focus or their small size with dedicated devices worn at all times.

Furthermore, this choice enables to target several children at once, on the opposite of targeting drivers, which would require a much wider setup.

More specifically, the prototype will be designed to target group excursions of children during the day. Indeed, the presence of adults ensures a proper use of the prototype and a correct setup: for example, teachers can make sure that each individual device worn by the children is carried properly and functional.

Then, by relying on the presence of an adult, simple signals can be used, as the teacher doesn't need more to understand and solve critical situations as long as they are brought to his or her attention. This eliminates the need for complex automation or heavy computational capabilities and enables the developed prototypes to stay simple and cheap.

Moreover, targeting the children while they are traveling during a group excursion enables to target a number of them at the same time. As explained in the previous part of this research, devices like the OJAS can then be used to offload powering of the prototypes to a master unit, and thus keep the children's devices simple, light and cheap.

Finally, preschoolers already use safety devices during excursions, which can be substituted with this study's prototype while still requiring minimal behavior changes or preparation. As confirmed by a preschooler teacher during an interview, improved solutions for children safety are always welcome, since current solutions have obvious shortcomings, as will be detailed in a further chapter. This is an additional reason not to focus drivers for the prototype, as adults usually have a resistance to change (Diamond M. A., 1986) while children are submitted to the authority of the supervising teacher.

The last step is to decide which specific moments will the prototype primarily be intended for. The obvious choice is to focus on the peak of the crisis: during winter – which accounts for a very high share of the victims, as clearly highlighted by the statistics detailed in the previous chapter. In Finland, it is dark most of the day during the months of winter, which makes it really the most dangerous setting regarding traffic accidents and visibility, thus the most critical situation to act upon.

II.3.c.THE CURRENT DANGERS IN THE CHOSEN SITUATION

After defining precisely the context that this study will try to improve by developing a dedicated wearable prototype, here is a summary of the challenges at play in this context, which were detailed earlier in the present thesis:

Firstly, children between 2 and 7 – the targeted age group of this thesis – often have a limited attention span, making it easy for them to get lost when in unfamiliar environments. Considering this lack of focus capability, children need to be grouped and supervised by adults, who will make sure that they stay safe at all times.

Then, it has been highlighted that children that young also present an unpredictable behavior, because of their important ability to detach themselves from reality and form complex fantasies in their mind, losing touch of their actual surroundings. Once again, this factor underlines how important it is that children stay grouped in an organized fashion during excursions.

A third danger threatening children in their outdoor movements that has been pointed out is their limited cognitive capacities, which makes them virtually unable to assess if a situation is dangerous or not. On top of that, the lack of essential notions such as the cause/principle can leave them oblivious to the fact that they are the one responsible for their own safety. This fact proves that preschooler's safety currently has to rely mainly on their accompanying adults, and thus validates the potential for a more advanced device helping them in that task.

Moreover, young children also lack the required experience of traffic to actually hold the key elements necessary for a safe interaction. This is one more reason why it is primordial to ensure that children do not make their own decisions when it comes to behaving in proximity to ongoing traffic.

Finally, physical factors like their smaller size make them inherently sensitive to traffic accident, making them harder to notice for nearby vehicles.

These are the main factors that were uncovered by the literature and statistics analysis regarding to the challenge this thesis is focusing on. Other factors with potentially negative impacts have also been gathered from interviews such as a possible resistance to authority or stubbornness from some children in specific situations for example. Now that a clear vision of the challenges to solve has been established, the next step of this thesis will be to make sure they are addressed in the prototype design phase.

The next chapter presents the methods used throughout this research, detailing the followed process and ensuring the validity of our solutions.

III.RESEARCH DESIGN AND METHODS

III.1.MATERIAL AND METHODS

The first step in this research was twofold: gather data about the existing situation of children safety in Finland and investigate existing wearable technologies and then try to highlight the most promising potential regarding this thesis' goal.

Gathering data about children safety in Finland was central to validate the relevancy of this thesis and the interest it brings to the current situation. It also provided insights about which situations and general conditions are currently the most dangerous and should be especially investigated and researched. It was first achieved by looking at official statistics to get an overall quantitative look. Numerous governmental departments or other organizations keep track of such figures in very documented and reliable ways, pointing out towards where to lead further investigations to find the current possible improvements. Then, reading literature from scientific research and studies yielded a global qualitative overview of the situation. From there, empirical data from interviews was collected from as many involved parties as possible. It is very important for this research that actual stakeholders can give their insights before starting the development of a solution, as they hold the most relevant insights that will give the required legitimacy to this research.

An additional prerequisite of this investigation was to choose which involved actors to target with the intended solution. Indeed, after finding out which existing problems should this research try to solve in the context of outdoors children safety, the parties involved in the problematic situations needed to be specifically defined. Precisely outlining their respective roles enabled a logical decision to be made regarding the most appropriate target group for the solution, to find out at which point of the sequence of events to act as well as to provide leads on how to practically get the most efficient impact. This will indeed serve as basis for the prototype building, creating a canvas for the actual design of the solution and supply insights on how to approach the specific problem it will tackle.

Data on wearable technologies was mainly gathered from literature written by field experts in regard of the problems that have been highlighted in the first phase.

The second step to be taken is to find and design a solution with the available technologies to overcome the problems at hand. Once again, stakeholders' insights will be central to this phase. From the original direction to strategic design choices, it will be of the highest importance to validate the solution's features and purpose with real-life constraints in mind. Thus interviews and ideation workshop will be held to come up with core ideas and define them to a stage at which the most promising can be implemented.

This will start the third phase of the research, with the actual technical design and implementation of a wearable technology prototype, validating with empirical data the assumptions made along the design process based on the gathered information.

This way, this research will definitely assess if and how wearable technologies can improve children safety in Finland. The findings gathered during this whole thesis will be analyzed and organized enabling a precise listing of the impacts on the studied problem, as much as made possible by the available data. Conclusions on whether children safety could indeed benefit from the use of wearable technologies or not will be presented, pointing out specifics and caveats to avoid, based on the research.

III.2. SOLUTION DESIGN PROCESS

The core of this thesis is to design a solution for the studied problem. This has been done according to the following process, based upon the common design model of the "double diamond" (Design Council, 2006).

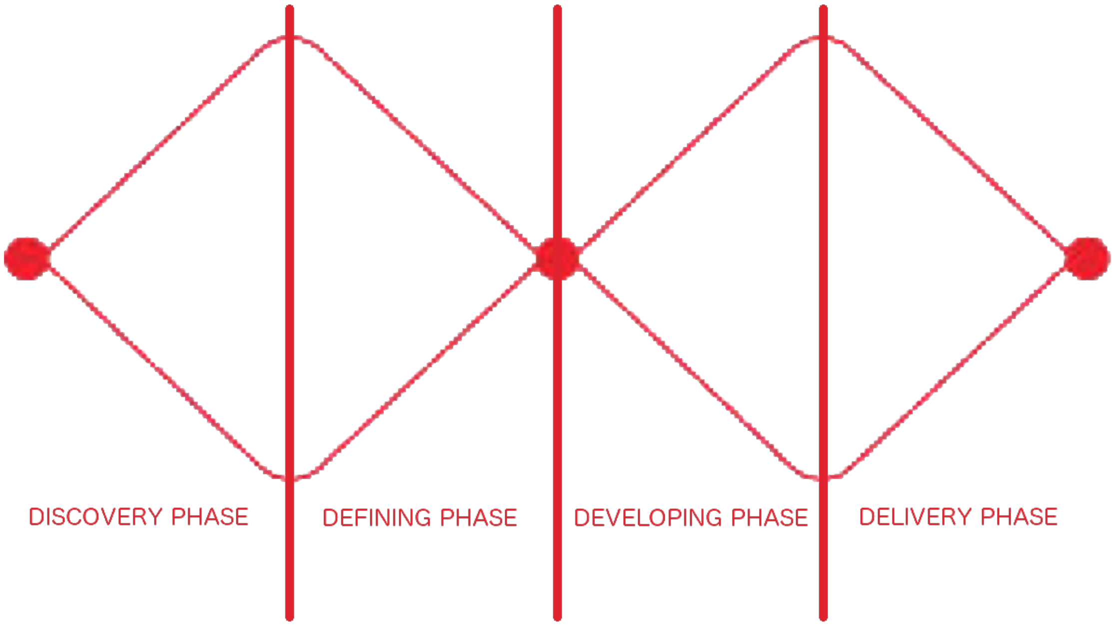

Figure 11 – Double Diamond design process defined by the Design Council (Design Council, 2006)

This process is divided in four phases, which in the present case are as follow:

The first phase is the discovery phase, during which as much relevant information as possible is gathered. This was achieved by the background analysis, on which results the design is based. This analysis indeed yielded a deeper understanding of the global problem of traffic accidents involving children, thanks to accurate statistics provided by official organizations, as well as earlier scientific publications about similar challenges from several experts in the studied field.

The last part of this background research focused on the actors at play, and enabled to separate their individual roles and thus uncover the most relevant target group for the solution to design. Furthermore, the final outcome of the background research was then the exact context to focus on – decision based on all the hard facts previously gathered – enabling the prototype to target a specific problem instead of trying to tackle the global challenge at once. In the double diamond process, this was the second phase – the defining phase – during which the problem is defined precisely in order to be able to start building the solution.

From there on, the third phases needed to be achieved. According to the framework, this developing phase consists of another opening of the research, getting additional information specifically on the chosen context, and detailing all the challenges involved as well as ideating around the possibilities to solve them. This was achieved here by interviewing preschool teachers about the current situation regarding excursions with their class, the problems they encounter and their own solutions. In the same time, ideation was carried out in order to find potential directions to improve the existing solutions or even tackle currently unsolved challenges. The results from the ideation were then presented to the teachers in order to get relevant feedback, as well as provide the teachers with early examples, making it easier for them to contribute to the ideation, or build on top of these ideas.

More precisely, the outcome of this third phase was double: first, it enabled to list all the most relevant problems (for example the visibility of the children) and then, it yielded their general solutions (for example adding light or sound to the children's outfit) validated by the preschooler teachers' feedback.

The final phase is thus the delivery stage, during which all the previous outcomes are combined into the actual prototype. In this study, the most critical problems to solve were chosen along with the most relevant way to solve them. From there on, the practical implementation needed to be done: first by discovering practical ways to implement these general solutions thanks to several early tests, before actually starting building the prototype according to the results of those tests. The building process in itself has to be iterative, starting from a minimum viable product and solving technical and usability challenge thanks to additional tests and feedback, enabling continuous improvement of the embedded interactions and features.

III.3.IDEATION METHODS

After explicating the general process of this research, the following chapter will present in more details the methodology used in the third phase:

the developing phase. This phase happens right after the context of the research has been investigated, and a specific setting defined. This stage aims at gathering data on the best ways to solve the problem at hand, and it has been achieved through the following steps.

III.3.a. INTERVIEWS

Once the context of the needed solution was chosen and the actors to target decided, it was important to gather first-hand information from knowledgeable sources about the current situation and its shortcomings. The best solution was to carry out interviews, and get elaborate data around the preschooler excursions.

Obviously, two groups of people are closely involved in that context: preschoolers and their supervising adults. Given the limited amount of information available from the preschoolers themselves, interviews were focusing on the teacher's point of view. Indeed, they are the ones that are responsible for the children, know and understand the practical reasons for the existing danger, and most importantly, are also trying to minimize it with their own solutions.

In the context of this thesis, two interviews were held with different preschooler professors. The researched objective was as mentioned earlier that data and ideas came from directly involved parties.

The first interview was held in a kindergarten in Eastern Helsinki, rather far from the center – so with a limited traffic to cope with during excursions, and a bigger available safe space for pedestrians to walk. It took the form of a semi-open discussion with a preschooler professor, and two assistants, each responsible for different groups of children. In particular, the professor was in charge of children with special needs, so even more affected by the challenges mentioned in the literature review – such as a bigger lack of attention – and thus more vulnerable to accidents during excursions.

Practically, the interview resulted in a one-hour talk during which the interviewees were guided around critical points of this research when required, to keep the discussion flowing: children excursions, their challenges, riskiest situations, existing solutions, possible improvements, etc.

Overall, the classes were composed by children aged between 1-3 and 3-6, precisely in the desired targeted age group, with the physical and cognitive development investigated in the literature review of the previous chapter.

The second interview was held in a very central preschool in Helsinki, where traffic was a very important factor during excursions with children. The interviewee was a preschool teacher, in charge of a class of around 20 children aged between 2 and 4. She has been teaching for twelve years teaching in primary school, before a four-year experience with preschoolers.

This second interview was slightly less oriented than the first, as an attempt to let the interviewee talk freely about as wide topics as possible – while keeping a link to children safety – and resulted in a longer three-hour exchange. Letting the interview flow on wider topics enabled first to uncover facts that would not have come into the discussion otherwise – as sometimes they came up while talking about indirectly linked topics – and second to act as a sort of ideation workshop as well.

Indeed, a brainstorming ideating session was held in between the two interviews, which is detailed in the next paragraph. Thus, the first interview was held as a basis for this development phase, mainly to gather facts on the existing situation. The yielded early ideas were used to understand critical points required by the prototype and as a basis for the brainstorming session. During the second interview on the other hand – while facts were also gathered and enabled to validate both the theory and the first interview outcomes – a more ideating process was also carried out, which was achieved by the following two steps.

For each challenge identified during previous phases of the study and for which brainstorming was carried out, the interviewee was first asked for her opinion on possible solutions – without any restriction of feasibility – and then presented with the outcomes of the brainstorming session, and asked for comments and improvements. This enabled to validate or not the concepts from the brainstorming, based on an expert's opinion on the matter, as well as improve them according to her opinion.

The results from this interview are basis for all the potential solutions and features for the prototype, which are detailed in the next chapter.

Finally, and as a side note, a short informal discussion was carried out with a preschooler about his perception of excursions and why there was a need for safety devices and guidelines. This talk corroborated several facts uncovered during the interviews such as key points to focus on while developing the prototype.

III.3.b. BRAINSTORMING

After the first interview was carried out, a lot of information was available from both theory and practical opinions about the problems of safety during preschoolers' excursions. It was thus possible to start ideating around the uncovered challenges and find potential solutions.

The brainstorming session was held over the course of an afternoon, and the author was the only participant. It was in fact researched and highlighted several times that individual brainstorming can be more efficient than group brainstorming (Madsen D. B. et al., 1978) (Rietzschel E. F. et al., 2006), which led to the decision of not involving other participants at this stage.

Methods for individual brainstorming were carried out in order to generate as many ideas as possible, such as drawing a mind map – a technique used to visually illustrate one's thoughts and their relations as a diagram – or writing down on post-it as many potential solutions as possible for a given problem without any self-censoring, may it be because of feasibility, logic or efficiency.

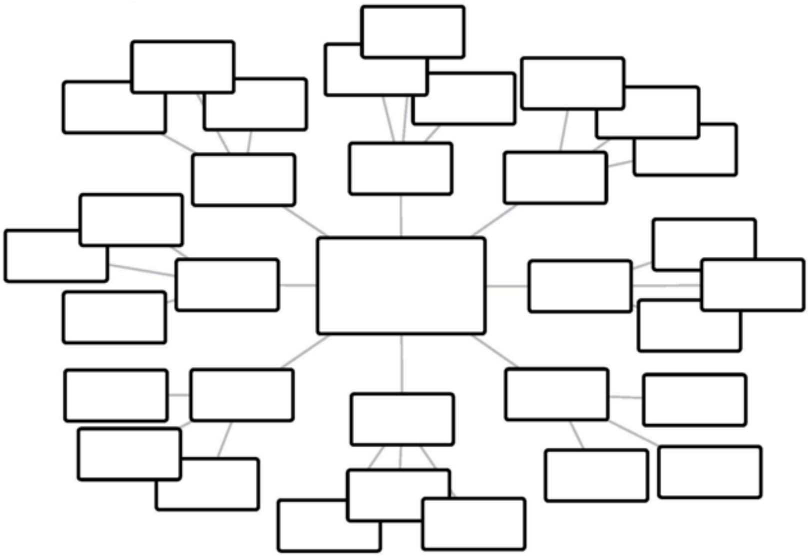

Figure 12 – An example of mind map template

source: http://lifeyourway.net/design/printables/mind-map-template.jpg

This brainstorming session yielded a number of potential solutions to all the challenges related to children safety, and a few of those solutions were found the most relevant as how to improve the situation, and it was decided to focus further development of these ideas for only the corresponding challenges. In other words, the final results of this brainstorming were composed of a selection of what were thought to be the most efficient challenges to focus on, along with potential solutions uncovered during this ideation process.

It is these challenges and solutions which were presented to the interviewee during the second interview, enabling even further development of the most interesting of them, thanks to validation and feedback from the preschooler teacher.

IV.FINDINGS

IV.1.DESIGNING THE PROTOTYPE

The present part of the research will focus on the results of each of the steps that were followed to achieve the design process, as they were explained in the previous chapter. First, the data gathered from the interviews is given as well as the results of the brainstorming. Then, combining data coming from both parts, the challenges deemed more important to tackle with the prototype are detailed, along with chosen practical implementations for their solutions. Finally, the features that are actually implemented in the proof of concept are presented along with the functional prototype.

IV.1.a.DATA GATHERED FROM INTERVIEWS

The following paragraphs hold the data gathered during the interviews, first presenting the current situation, before detailing the current challenges as seen by the interviewees and their existing solutions.

IV.1.a.i.THE DAILY SITUATION

There's a lot of preparation before an excursion. The children are prepared mentally and given guidelines to follow such as "we will not run" or "we will give hands and behave" as well as information about the trip. They understand that it has to be calm, and that they can be punished if they don't follow the rules.

To check that no one was lost, the teacher regularly counts the children after asking them to stand still or in line during the process, which is usually achieved easily. The teacher is also required to have the list of all present children at all times – to check who is missing if needed – along with their personal information. Usually, the list is not necessary as teachers can check visually, even if there are a lot of children, as they know all the children personally. They also have an idea of the potential 'problem' children, who they will look for first, as they are the most probable to slip out. To make the children behave, they can punish them if need be: common threats can be isolation, not coming on the next trip, etc.

When a child refuses to obey, isolation is usually very effective, because children don’t want to be left alone and want to be a part of the group. Very rarely, it might be required to carry the child back to the school: this is very humiliating for the kid and is thus a very big punishment.

During the first interview, it was highlighted that safety was an issue to the point that not many excursions were organized anymore nowadays because there were too many children to look after for too few professors. On the other hand, it was mentioned during the second interview in the center of Helsinki that given the school premises small size, no internal playground was available, and thus the excursions to the park happened everyday.

This proves once again that in both situations, a need for improved safety during excursions in an easy and reliable manner was of great interest for the children and their supervising teachers.

IV.1.a.ii.MOST COMMON CHALLENGES

The biggest problem that emerged from the interviews is the fear that a child escapes the vigilance of the teacher and manages to run away and get lost. In fact, when children manage to go relatively far from the professors, they might not pay much attention to their surroundings, and put themselves in dangerous situations. This is why those trips are also experiences to teach the children how to behave and pay attention outside.

Traffic is also a big threat, but in a more indirect way, considering that if children stay under close supervision at all times, the risk of dangerous behavior is minimal.

However, even with proper supervision, crossing the street is a big challenge, as it puts the children in direct exposure to traffic, and accidents can thus happen before the teachers have time to react. It is a complex process, as the teacher needs to gather all the children close enough to the road while still safe from traffic, and then wait idly for the appropriate time, which can be hard for children to achieve. Nevertheless, vehicle drivers are usually really understanding and helpful, crystallizing the risks once more on unexpected behavior from a child or a lack of visibility from the driver.

Then, taking public transports is very challenging because the professor needs to pay attention to other factors than the children – like paying or next stop – and there is an increased interactions with external people, which can disturb the usual process of the teacher. Furthermore, public transports can require quick reactions – to get in and out of a bus for example – and consequences can be much more dramatic if something doesn't go right – like a child getting off at a wrong stop for example.

IV.1.a.iii.EXISITING SOLUTIONS AND THEIR PITFALLS

The solution for dealing with public transports is to avoid them as much as possible, and when they are really required, avoid rush hours to make potential trouble as minimal as possible. This is a challenge that is quite out of the spectrum of this thesis, and was presented because it was mentioned as one of the most important during excursions in the city.

The most relevant challenge here is thus the supervision issue, or how to keep the children organized at all times, so that teacher can make sure that the children don't put themselves in danger.

A few solutions were presented during the interviews, each with their own shortcomings:

A first one was to use buggies: The smaller children are installed inside buggies, while older ones grab them on the sides. This solution has the major inconvenient of requiring a relatively high number of buggies. Indeed, a buggy takes care of only four children while requiring one adult to push it. During an excursion, there can be as little as three adults for twenty children. Two possibilities are therefore used: either the other children walk around without buggies, or the oldest children of the group also push some buggies. Both have obvious safety problems, limiting the efficiency of this solution.

Figure 13 – An example of preschooler buggy used during excursions

source: http://www.bikemania.biz/media/catalog/product/a/n/angeles_bye-bye_fb6300f.jpg

A more classic solution is to make the children hold hands two by two and walk in aligned pairs. While this solution doesn't require any device and can virtually take care of any number of children, it requires children to be able to stay organized on their own, as well as walk in a close group without external help. This is the solution used for older children, but in the context of preschoolers, this is not realistic, as children can't walk in organized fashion without help, making this impossible to apply in the context of this study. Furthermore, quarrels are a common thing between children holding hands, and if they don't understand the importance of staying in line, arguments can lead a child to quit the group unexpectedly, thus creating a dangerous situation.

However, a third solution is to use a rope, which solves these shortcomings of holding hands, while keeping the advantages. Ranging from a simple rope to a more advanced device with handles and reflectors, ropes can be used as external help to keep the children organized. Most often, distinctive marks – such as colored tape – are placed on the ropes indicating to children where they should hold it. From there on, the teacher can lead the whole group of children while keeping them in line without any effort required on their part, as long as they hold on to the rope. This is indeed the main shortcoming of this solution: if children let go of the rope, it can go undetected by the teacher. This is not an uncommon situation, as holding on to a rope can feel like a punishment for the children, and they don't might want to let go after a while.

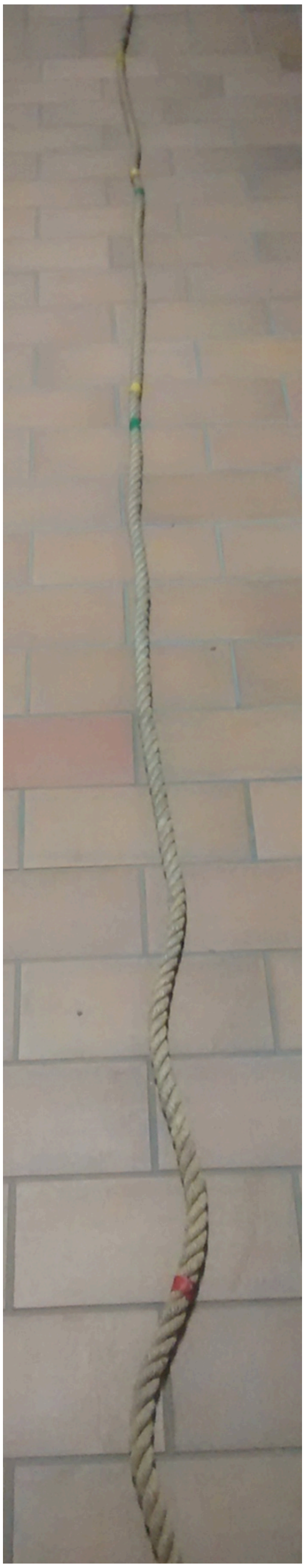

Figure 14 - The rope used by one of the preschooler teacher interviewed. Colorful tape is visible indicating possible grabbing positions to the children.

Finally, a common solution to the visibility problem is currently to put reflecting vests on the children during excursions in winter, making it easier for cars to see them.

Figure 15 – A preschooler wearing a reflecting jacket

source: http://www.highway1.co.nz/uploads/6/4/7/1/6471244/9277553_orig.jpg

IV.1.b.THE CHALLENGES AND THEIR GENERAL SOLUTION

In this part, the outcomes of the first step of the brainstorming session are presented. The challenges linked to preschooler excursions have been grouped into categories for which several angles of solutions have been uncovered. In this first step, the solutions purposely remain on a general level. In fact, precise solutions to the most relevant challenges in the context of this study are detailed in the next part of this chapter.

The first type of challenge that has been uncovered earlier during this research stems from the children's limited attention span. A direct consequence of this is that children need as close supervision as possible. In the current situation, teachers reported that this requirement is hard to fulfill because of the limited number of available adults. Furthermore, this sometimes gives passing adults the impression that external help would be beneficial, pushing them to interfere and often worsening the situation. To solve this problem, the following directions are possible: individually monitor the children, actively focus their attention on a controlled factor like a common activity, understand and predict their behavior or simply organize them to minimize undetected dangerous behavior.

The second problem that was highlighted is due to the limited cognitive capacities of the preschoolers that often behave in unpredictable ways and unintentionally put themselves in danger. As previously explained, it is not uncommon that children are not able to grasp the danger of incoming vehicles, and when drivers assume they will react in the usual rational way, accidents can happen. In this case, two directions were available: actively scanning for danger in real-time, warning the child if his or her behavior is dangerous or make sure that dangerous situations will not happen by efficient prevention.

The next challenge comes from their physical characteristics, such as their smaller size, that makes children harder to see for a driver and puts them in an unsuited environment, thus becoming especially vulnerable to traffic accidents. Potential solutions here are based on making up for these differences to reduce the vulnerability:

- making the children more visible by setting light or sound on them
- introduce additional movements to catch attention more easily
- make the children appear taller,
- or once again group them to make them more noticeable.

Finally, the last category of challenge is related to the children's situation. A child in a group supervised by a teacher can for example create defiance towards authority, which can make him or her hard to protect. The implementation of the solutions to the previous problems has to take into account the fact that children will not necessarily cooperate even if it is against their own good. At this point, it is possible to enforce safe behavior by the threat of punishment or make the children want to adopt a safe behavior. The latter can be done either by explanation and education, making sure the children understand the point of the guidelines, or indirectly make them adopt a safe behavior, for example by motivating them through fun.

Regarding the current situation, the data gathered during the interviewed showed that the existing solutions such as the rope, the buggies or walking in organized pairs tended to rely on the following possibilities:

- Organizing and grouping the children
- Prevention rather than detection
- Enforce safe behavior through education and punishments

However, wearable technologies make for smarter and more capable solutions, and provide the possibilities to benefit from other potential directions mentioned in the previous paragraphs. The next part presents which solutions have been chosen as most promising and developed further to fit in the prototype design.

IV.1.c. THE MOST RELEVANT CHALLENGES AND HOW TO SOLVE THEM

In the context of this study and based on the evidence gathered in the theoretical background analysis as well as the data from the interviews, the following directions have been chosen as basis for the prototype features design.

The solution will prevent danger rather than trying to predict or detect it. In fact, the focus will be put on keeping the children organized at all times, preventing dangerous situations to happen. This has been decided based on the fact that aiming for prevention is preferred over crisis situation management. Indeed, by grouping and organizing the children, it is possible to prevent the children's erratic behavior before it ever happens, and thus avoid the development of risky situations. Furthermore, prevention is somehow more efficient. For example it can prevent the risks of traumatism that would be inflicted to a child even in a no-damage accident.

On a practical level, prevention is also easier to implement. Crisis management indeed requires setting up a sequence of action depending on the situation. It would also call for automation and complex active devices – for example monitoring in real time each child surroundings for danger – and this is not achievable with the resources of this study: each child's prototype would need an actively powered device with its own computational power. Besides being too complex and expensive – making it less relevant for the context of public safety – basing the solution on prevention keeps the responsibility on the supervising adults, who stay in total control of their class without interference from external devices.

This will be achieved by building the prototype around the rope solution, best existing solution to keep preschoolers grouped, as highlighted during the interviews. Furthermore, keeping the prototype form factor close to a current solution will make it easier for the teachers and the preschoolers to adopt.

On a second step, the prototype will use light as a main feature, for the following reasons.

As it was described during several parts of this study, the lack of visibility is one of the most important factors in this research: children are vulnerable because of their small size, and in general because bad visibility conditions – such as during night or winter – are a leading cause for accidents. Using light is thus one of the most efficient means of action in the studied settings: it is in fact dark most of the day during the deadly winter months in Finland.

Furthermore, light provides the advantage of being usable without major disturbance to the surroundings, as opposed to sound. Integrating sound would make the children more noticeable but also be a major disturbance, for other pedestrians and occupants of the surrounding buildings as well as the group of preschoolers themselves. The main point remains that it wouldn't be efficient in noisy urban areas, and would go mostly unheard by their primary target: the drivers. Using light is thus the simplest way to make the children more visible with minimal negative side effect. This decision is also based on the fact that light is the *de facto* standard when it comes to visibility, used by all vehicles and widespread by street lighting in urban areas.

Finally, light can easily be made into an incentive to use the prototype for the children. It can be used as a mean of creating fun through a futuristic feel or interactive capabilities. Light patterns could for example be used to create shapes or drawings recognizable and appealing to the children only if they follow the guidelines. The importance of incentivizing use of the prototype is detailed in the next part of this chapter, focusing on the specifics of dealing with children.

Finally, it was emphasized multiple times during both interviews that one of the most critical point stands at the moment when a kid escapes from adult supervision. This specific situation should thus be one of the biggest focuses of the prototype. A dedicated feature to this specific problematic needs to be implemented, with a focus on keeping this solution as simple as possible. The implementation of this concept has basically two ways to go: monitor the power income of each child's jacket and raise an alert when it is interrupted or monitor the power consumption on the rope, and alert in case of brutal change. The first case requires adding a monitoring mechanism to the jackets, as well as a way to send an alert even though the power source is cut. Thus, the latter solution is preferred, and the alert mechanism will be situated on the rope.

IV.1.c.i.DEALING WITH CHILDREN

As mentioned previously in this research, the fact that the target group is composed of children requires some specific attention.

Due to the very nature of children that don't necessarily grasp the importance of the device, they are hard to keep focused and can also sometime defy authority against their own good. Thus, it is important to create a prototype that doesn't feel like something the children have to do. One of the most interesting ways to achieve that is to make it fun. Indeed, one of the teacher interviewed affirmed "children are more inclined to do it if they have fun, and not if they feel like it's mandatory". The idea here is to take advantage of the children's growing imagination in their favor by empowering it to act in favor of traffic, instead of leading them into dangerous situations. Having fun gives another purpose to the prototype, one that children can fully understand and that motivates them: instead of being forced to do it for their safety that they don't understand, children deliberately choose to use the prototype if they think it is fun to do so. This way, it is possible to improve the current model used to ensure obedience based on punishments in case of misbehavior. In the end, the preschoolers are still protected even if are not necessarily conscious of it, and that is the most important factor.

Another factor is that the device can focus the children's attention on their immediate surroundings in order to try and prevent dangerous behaviors, but the device can't ask for their full attention. In fact, one of the learning points of outdoors excursions is that preschoolers get to learn how to behave in traffic. If the prototype asks for too much focus, a negative side effect is that children are not paying any attention at all to their surroundings, and thus will not learn why and when to stop for traffic, or where and how to cross a street by watching their professor. This is an important balance that the prototype will have to respect, which prevents complex uses that would require too much attention such as embedded games.

Finally, a last important point related to the children is that they can't be expected to be responsible for themselves. In a first step, this means that the prototype has to be efficient without any conscious action required from the user. A second point is that it is important to design the prototype so that children cannot easily break or lose important parts of the device, which would prevent proper use. In the studied context of a primary focus on winter settings in Finland, a simple solution is to built the prototype into the usual protective clothing, and as such, making it hard for the children to lose. Would it be part of an additional bracelet or something that is worn over the clothes, the children could discard them easily. However, if it is freezing and the device is integrated in the mittens, the probability of accidentally losing it is lower.

IV.1.c.ii.SITUATIONAL CHALLENGES

Finally, some additional challenges linked to the context of use exist and need to be taken into account before moving forward.

A first important thing that was mentioned during the interview is that excursions typically involve a very small number of adult supervisors in comparison to the number of children to take care of. According to the interviewees, the typical situation is around three adults for about twenty children. This implies that the supervising adults have already a lot to think about and focus on, and while the prototype is dedicated to improve this challenge, it needs to be reliable and require minimum setup time and complexity of use not to add additional concerns for the teachers. This has been achieved by keeping the users in mind all along the design process, trying to keep the prototype as close to the existing case of the rope.

Additionally, the prototype will be intended to be used while on the move, so on top of being as easy to setup and use as possible, the prototype will need to be easy to carry. It needs to be as lightweight as possible to make its use not more cumbersome than a traditional rope, and further, it needs to be flexible so that it doesn't take too much space when not in use. Indeed, while reaching the excursion destination, teachers will have to carry the prototype around with them all the time. Making it flexible and as lightweight as possible will enable the supervisor to fold it and put it away in a backpack for example, as they would have done with a classic rope. Wearable technology is perfect for this kind of characteristics, thanks to the use of conductive thread that replace traditional somewhat stiff electric wires by completely flexible threads.

IV.1.d.HOW TO PRACTICALLY IMPLEMENT THESE SOLUTIONS

This part of the thesis will now present the most relevant outcomes of ideation regarding implementing the chosen solution direction detailed in the previous paragraphs. Firstly, the most interesting ideas that emerged are explained, before moving on to the actual features the proof of concept developed in this study's context will have.

Overall, the ideas presented below are all very good candidates for improving children outdoor safety because they address the theoretical challenges uncovered regarding children safety through a practical aspect approved by the interviewed professors. They would thus need actual testing in order to find out the most efficient of them. However, considering the discovery nature of this thesis, the proof of concept has been kept as a minimum viable product, and the prototype detailed in the next part only takes the most essential aspects of these possible features.

IV.1.d.i.IDEATION OUTCOMES

The first outcome was regarding the form factor of the prototype. As mentioned previously, it was found that theoretically, making the prototype a rope would be an optimal form factor, both for correspondence with existing solutions and usability in the usual settings of high ratio children/adults. However, the interviewed professors mentioned a few additional criteria when prompted about this idea: a rope would be fine to use as long as it is flexible enough. Indeed, a big rope can be cumbersome and difficult to hold and handle, especially when it is not in use and needs to be carried. The simplicity of the form factor and the fact that it can be made easy enough for the children made it a good decision, but the main focus needs to be on keeping it flexible enough to roll away even with embedding electronics. This has been explicitly taken into account while developing the proof of concept, as detailed in the next paragraph.

Another feature that would benefit the prototype is to allow flexible grouping to make it less of a hassle for the users. As a primary focus of the prototype is to keep the children organized at all times, it would be interesting to enable any kind of grouping instead of the classical two-by-two, in order to let children organize themselves as they wish, making them less inclined to change the organization unexpectedly at a later potentially dangerous moment. A possibility to achieve that would be to have a prototype that can accept chains of children instead of requiring direct contact with each one of them. By clearly highlighting all children that belongs to the group, the organization can be more flexible and bigger while keeping everyone safe at all times. An example of practical implementation is illustrated on Figure 16.

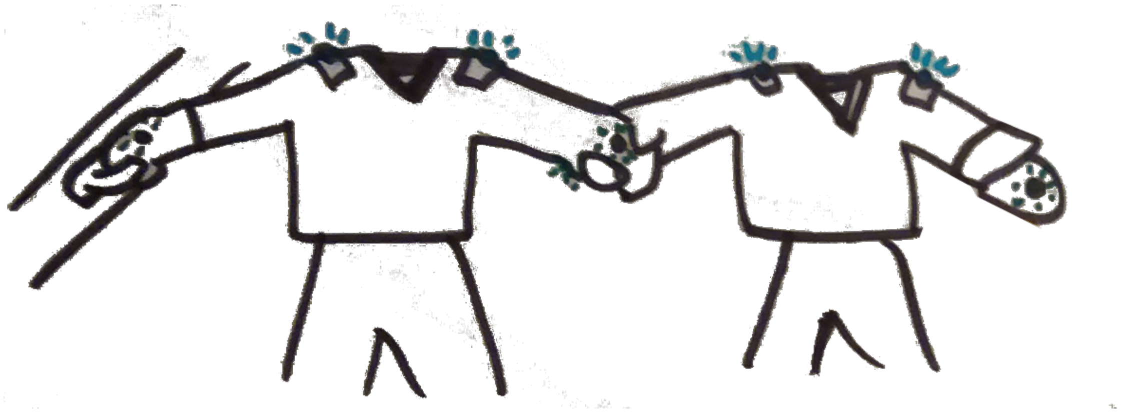

Figure 16 – Sketch illustrating the chains of children functioning

Then, a lot of possibilities were considered on how to monitor if children are unexpectedly leaving the rope. In fact, this has been presented as the most dangerous situation while going on excursions with preschoolers, and a warning feature would thus be most beneficial to the prototype. As decided previously, this feature will be implemented on the rope, for the main reason that it is powered at all times. The next possibilities are between a local and a global monitoring: this means that the rope can either locally detect that one children is missing and locally display it, or a global monitoring system could be set up at the professor's location presenting the global situation of the rope. In practical terms, it would be a LED next to the handles of the rope that would light up if a child were missing or a real time display of how many children are in the system.

The global monitoring system was deemed too complex for this task, while not significantly more efficient than a local monitoring. Furthermore, the interviewees thought that a screen to display which child is missing would not really be optimal because it would create an additional area to pay attention to, while they would prefer to keep their focus on the children. From there on, it was decided to implement this feature locally next to each child.

Another outcome that was found really interesting is to also add a feature that would help in case a child still managed to escape adult supervision. The classic way to do this currently is through individual nametags, with the school's contact information on, to help people finding a lost child to get him or her safely back. However, putting nametags on children has many limitations: first it is time consuming to prepare them and put them on the children. During the first interview, it was recognized that there wasn't time to take care of this before every excursion, and thus nametags were usually not used.

Then, no optimal form factor has been found for the name tags, as they need to be simple enough to be put on and of the children, be quite sturdy so the children won't lose them while staying safe for them (strangulation risks can exist for example).

Finally, by embedding more information in the prototype, teachers could finally replace the presence book with all children's personal information that they are currently required to carry at all times and which can be quite cumbersome.

A practical way to achieve this would be to embed critical information like the school contacts on the children's jackets in plain text along with a QR code leading to password protected personal information when flashed – as can be seen on Figure 17.

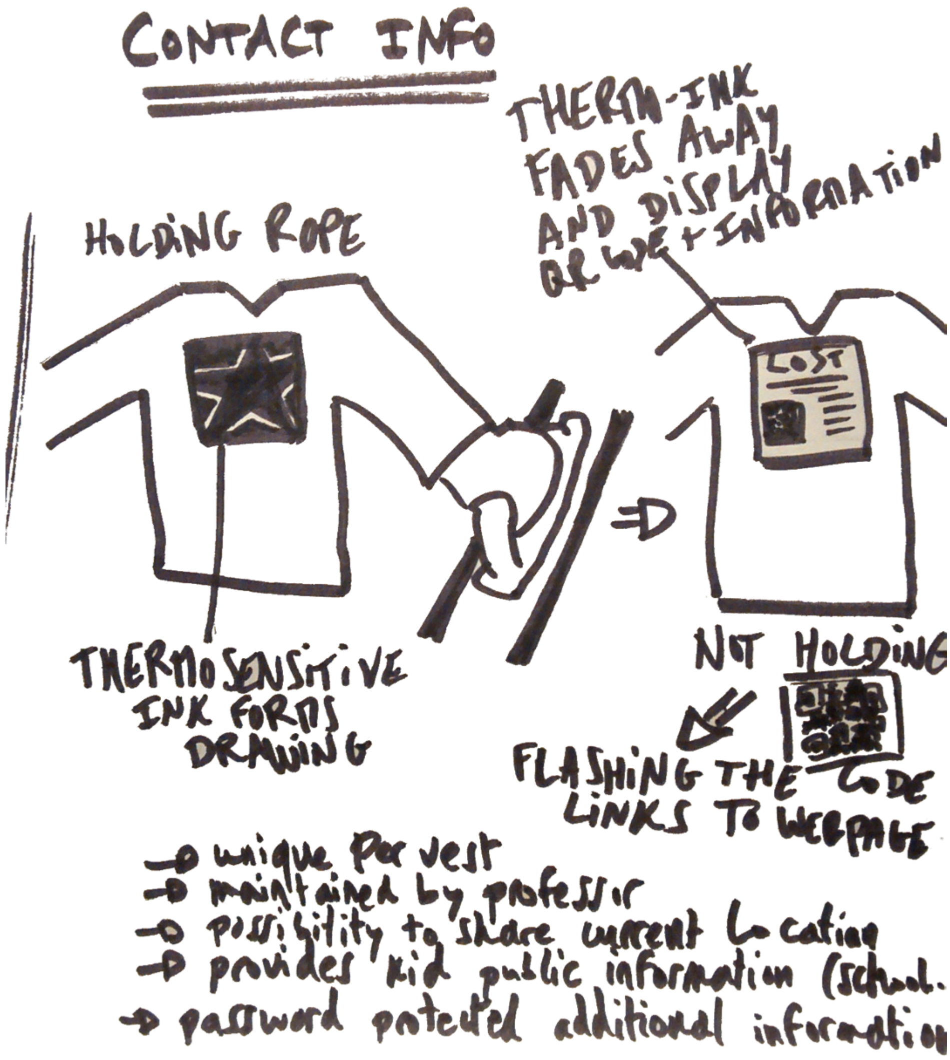

Figure 17 – Sketch of the contact information embedding

Furthermore, this text and QR code would only appear if the jacket loses its power thanks to thermo-chromic ink that changes aspect when powered (Jacobs M. et al., 2005), displaying a decorative shape otherwise. This way, the personal information could be updated from a computer without having to manually change anything from the jackets, and as much information as needed could be accessible at all time from the jacket, replacing efficiently the physical presence book.

From the children point of view, it has already been established that creating a rewarding experience for being part of the system was critical in order to provide them with a reason they can understand for behaving safely. A typical example of rewarding experience for the children was mentioned during the first interview as the “Batman logo” feature. In details, it was thought that if holding on to the rope would make the worn jacket display shapes that children would like to see on themselves, such as lighting up superhero logos or princess distinctive signs, the experience would become much more fun, achieving the aim of making the children want to hold the rope, all the while making them more visible to drivers. This seemed as a feature full of potential, for the appeal it had towards children, while still remaining simple and beneficial to the primary target of the prototype.

However, it was discussed during the second interview that such a feature would make the jacket more “fashionable”, and that it was not really the school’s role to decide whether or not to make children wear this kind of commercial brands and distinctive marks. In fact, embedding such powerful icons of the consumer society would possibly affect both the children and the parents in ways that aren’t supposed to be decided by a preschool’s teacher, and thus, it was thought that instead of using this appeal, the prototype could be used as a learning means.

In fact, the excursions taken by preschooler are mostly learning experience for them, aiming at teaching how to behave in a urban environment. From there on, a way to use the prototype would be to make this learning more efficient and more fun. For example, codes such as the traffic lights coloring scheme could be also used in the prototype to interact with the children, making them learn the meaning of the lights in an entertaining way. An illustration of this concept can be seen on Figure 18.

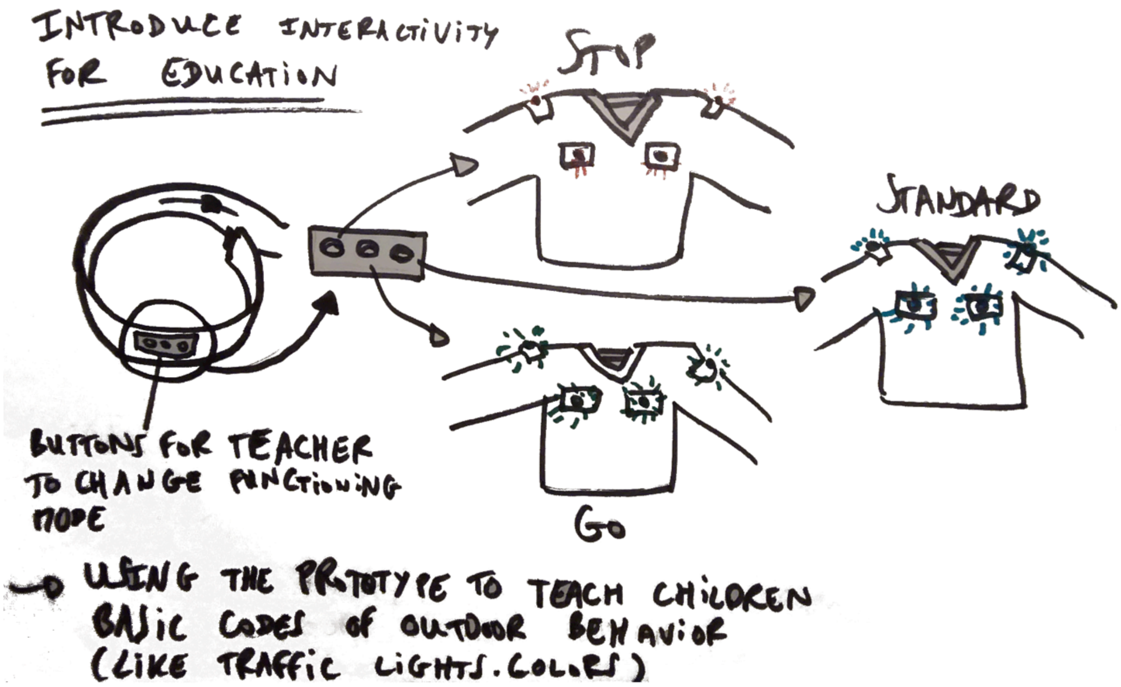

Figure 18 – Sketch illustrating educative possibilities of the prototype

It is important to remind here that interactivity was thought to be mainly counter-productive previously in the case of this study, as it could take away the attention span of the children from their surroundings and put them at risk again. However, in this specific case, the interaction is kept to a strict minimum and acts as a vector for the educating purpose, making it an appropriate way to integrate it in the prototype functioning.

These are the most relevant outcomes of the ideation phase carried out during this research, and all these features carry important values that would strongly improve the safety of preschooler excursions. The next paragraph presents the actual features that were integrated in the developed proof-of-concept- along with their origin from the ideation outcome.

IV.1.d.ii.THE FINAL FEATURES

The final proof of concept is composed of two main parts: a “rope” and a jacket that connect together.

First, the rope form factor is defined according to the key factors mentioned previously: it has to be close to the existing rope used in excursions, with distinctive marks for children to position themselves, and it needs to be as flexible as possible. Finally, it has to be a minimal distraction for the teacher. A basic sketch can be seen on Figure 19.

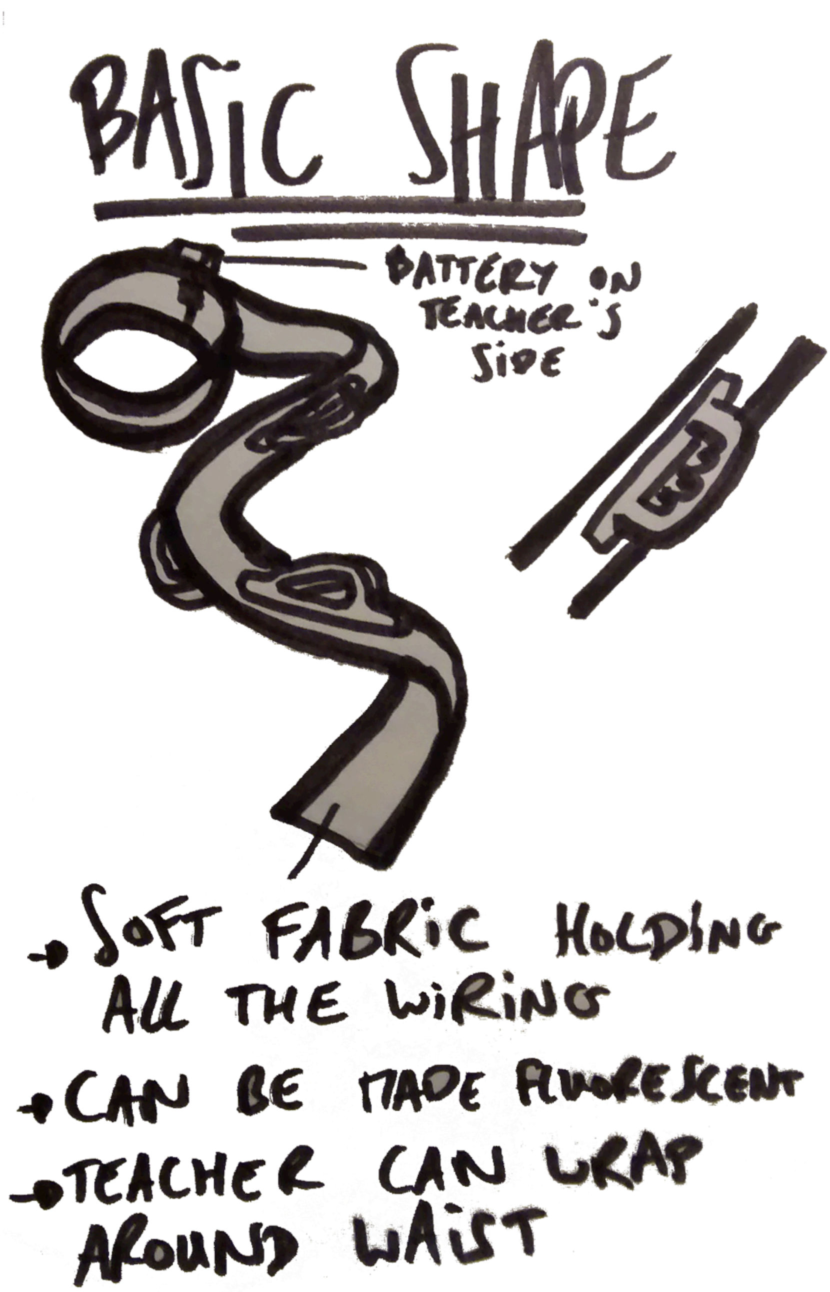

Figure 19 – rope form factor

In order to respect all these criterias, the rope is made of soft fabric, in which is embedded all the wiring. Handles are integrated at good distances to be able to define precise powering spots for the vests. The inner wiring itself is made out of ultra-flexible wires, so that rolling the rope is as easy as with a piece of cloth. Furthermore, in really critical part, such as the handles were several layers of fabric with embedded wires are concentrated, conductive thread is used to keep a perfect flexibility. Finally, one side of the rope is dedicated to the teacher, holding the battery, and with the possibility to wrap it around the waist. This way, the teacher can keep both hands free while using the prototype.

The most important part of the rope is of course the handle. They are both used to mark places with appropriate distance from one another so that children now where to position themselves, and as power outlet for the children's vest. Finally, the handles are also used for the detection of an unexpected departure of a child. A basic sketch can be seen on Figure 20.

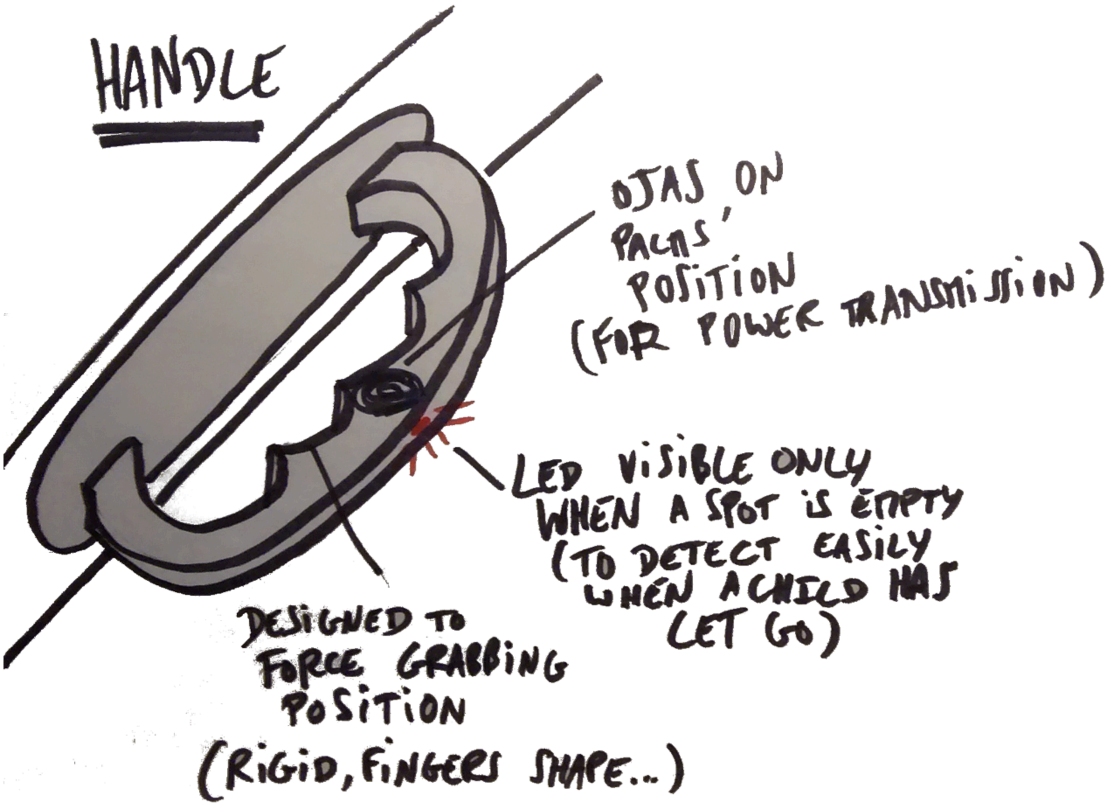

Figure 20 – Sketch of a handle on the rope part of the prototype

The powering part of the handle is managed by the OJAS device that was presented earlier in the thesis (Mikkonen J. et al., 2014), a very easy-to-use component enabling wireless power transmission. More notably here, the detection of leaving has been implemented in the easiest way: in order to keep this proof-of-concept as simple as possible, the system is composed of a simple LED, strategically placed. No actual detection is required, as the position of the LED makes it hidden if a child is holding on to the handle, and visible otherwise. This way, if a child let go the rope, the red LED becomes instantly visible to the teacher who can act consequently. This very simple system can obviously be upgraded into an active detection process, but was thought to be efficient enough for this first prototype.

On the other end of the handle comes the jacket. When a child is holding the handle, his or her jacket receives power through the OJAS, and it becomes active.

The powering happens through a glove that is attached to the sleeve of the jacket. The glove can be seen on Figure 21.

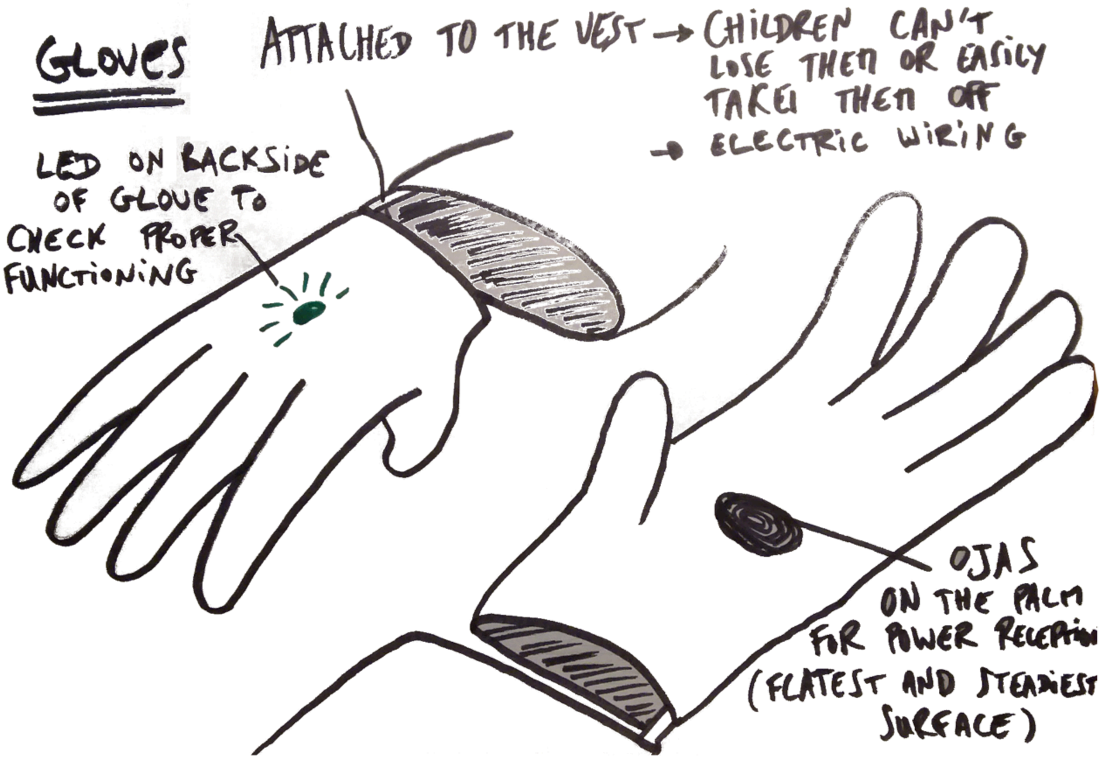

Figure 21 – Sketch of the glove attached to the prototype's jacket

On the glove, two components are embedded. First and most obvious is the OJAS in the palm, which comes in proximity of the handle's OJAS, enabling power to be transmitted. The position of the OJAS in the palm has been decided because it is the flattest and least moving part of the hand, making the necessary syncing between sending and receiving OJAS as easy as possible. Furthermore, a feedback LED is embedded on the back of the hand. This serves two purposes: first, it is a way of making sure for the child and the professor that the OJAS is receiving power properly as the LED turns on. Second, this green LED will give feedback to the professor that the child is indeed holding the handle. As a matter of fact, it is the corresponding part of the red LED on the handle, hidden by the child's holding hand. For the professor, it appears as if the red LED turns green when the child grabs the rope, which is exactly the desired behavior for monitoring that children never let go of the rope.

Finally, the glove is attached to the vest making sure that it can't be lost and that the children's vest will always be powered while holding the rope.

In the present case, the power received by the gloves is used to simply light on a few visibility LED, improving the visibility of the children, while making their jacket look more intriguing to them. The look of the jacket is illustrated on Figure 22.

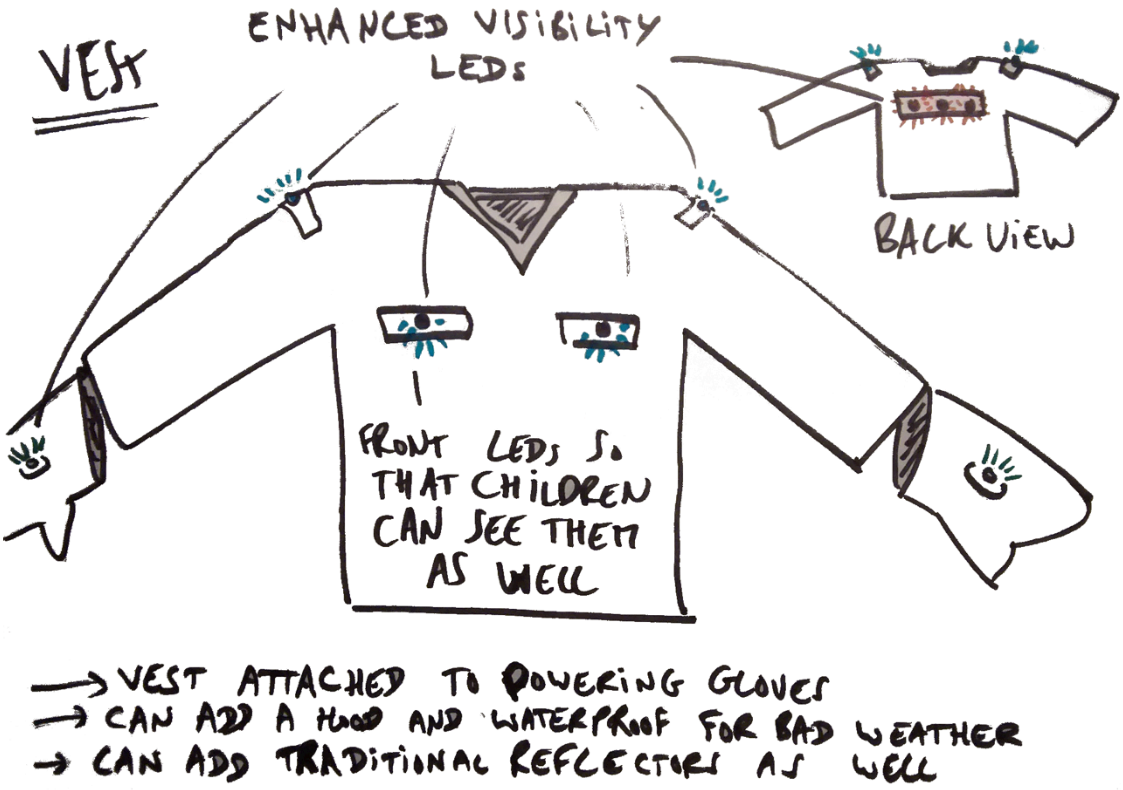

Figure 22 – Sketch of the powered jacket

This has been found enough to motivate the children to hold on to the rope based on the success of the basket shoes with embedded LEDs, that most children will find much more interesting than regular shoes. These LEDs also acts as warning lights for potential drivers and thus simply and efficiently help reduce dangers for the preschoolers.

To conclude, the design of this proof-of-concept has been kept as simple as possible, in order to be developable with minimal resources and time. However, it remains interesting as most main challenges uncovered previously are still at least partly addressed by its basic features.

IV.2. THE PROTOTYPING PHASE

After having defined precisely the design of the proof-of-concept, the next step was to actually implement it. A few challenges were met during this phase, and before presenting the results of the prototyping, the most significant challenges are presented.

IV.2.a. THE CHALLENGES MET

The first and most obvious challenge was the wireless powering of the jacket given the use conditions of the prototype. In fact, the prototype is intended to be used by a moving group of children who shouldn't need to be conscious of the practical requirements for the prototype functioning. On the other hand, the OJAS needs proximity and alignment for transmitting power efficiently. The first questions that needed answers were thus how strict these physical requirements were, and how to minimize the risks.

To minimize the risks of a child holding the rope to far from the emitting OJAS, it was decided that handles would be used, and made rigid so that only the best position for power transmission would be the most natural position for the child's hand.

On the technical side, the OJAS can theoretically transmit power strongly enough to power the jacket at a few centimeters range, as described by Mikkonen et al. in the OJAS publication. A few practical tests needed to be done, to confirm the theory, and thus, a receiving OJAS was held at different distance, angles and alignments from a handle to measure how much power could be transmitted in bad conditions.

As can be seen on Figure 23 showing two extreme cases of non-alignments, even if a child were to hold the handle really out of the intended position, the OJAS was still able to transmit enough power at a significant distance to power a high-voltage LED.

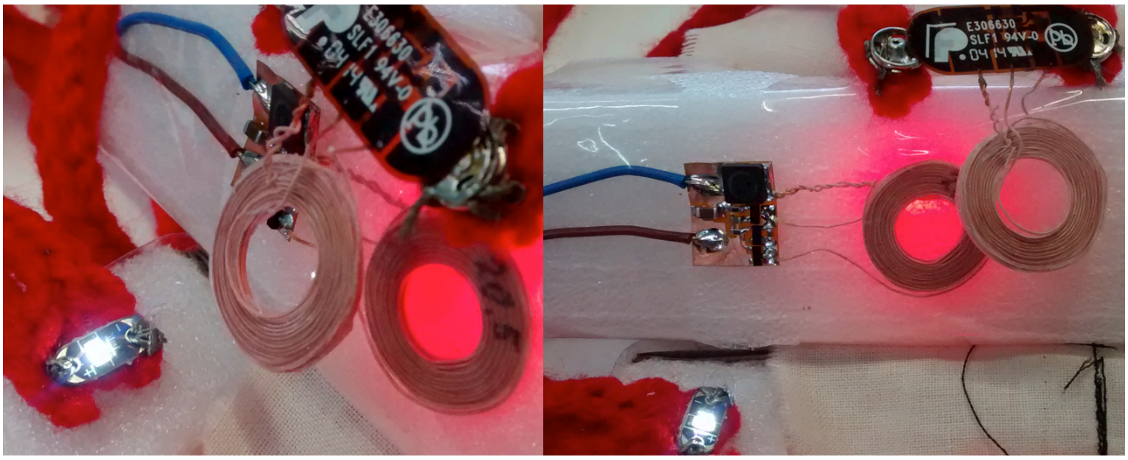

Figure 23 – OJAS alignment tests: a transmitting OJAS (backlit by a red LED) transmits power to a non-aligned, distant OJAS, which in turns powers a white LED.

This first challenge thus resulted in being much easier to solve than expected, with the rigid handle forcing the hand at a few centimeters from the OJAS being a constraint good enough for the technical requirements of the OJAS.

While designing the prototype, it was originally intended to use only conductive thread instead of traditional electrical cables. In fact, considering the small amount of required power, it was completely safe to use, and would allow a much more flexible rope than with wires. As a matter of fact, conductive thread behaves precisely as classic thread does, and as such is as flexible as the fabric used for the rope part of the prototype.

However, an important problem rose when using conductive thread: the prototype's rope being a few meters long, an important length of conductive thread was required to bring the power from the battery pack on the teacher's side of the rope, all the way to the handles at the other end. The available conductive thread being much more resistive than regular wire, using it over such long distances added up to a significant resistivity, preventing the power to reach the more distant handles. After a few measurements, as seen on Figure 24, it became obvious that this effect was non-negligible, and that conductive thread was to be replaced with wires for the longer distances.

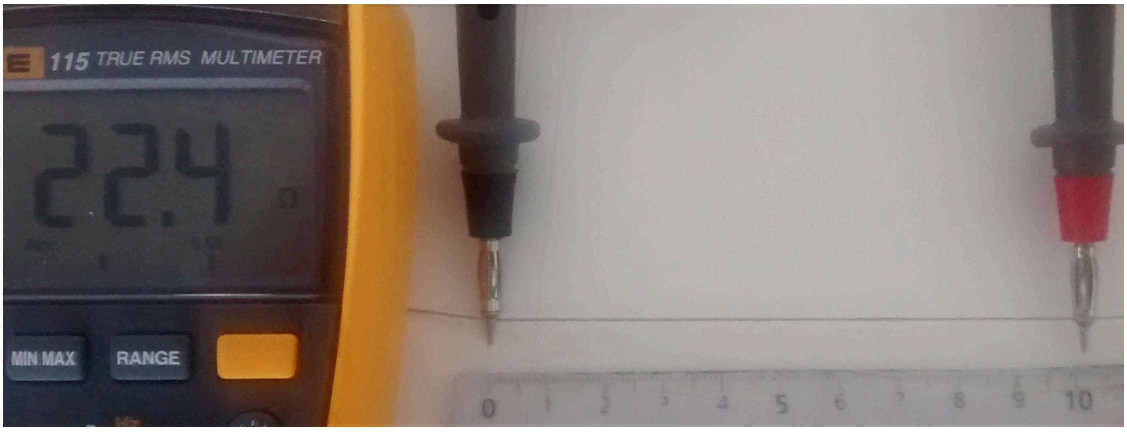

Figure 24 – Measurement of the resistivity of 10 centimeters of the available conductive thread, showing 22.4Ω

In this situation, it was still possible to use conductive thread in shorter distances, for example in the handles where traditional wires would have added stiffness. The longer wiring was however switched to ultra-flexible wire, keeping the prototype flexible enough to be rolled or folded, but still losing the appeal of being completely wired with thread thus feeling as a traditional piece of fabric.

Finally, a very significant challenge emerged with the design of the handles. The handles were originally planned out as illustrated on the sketch in the previous part: rigid handles – for power transmission – were directly fixed on the rope. An early version of the prototype looked as on Figure 25.

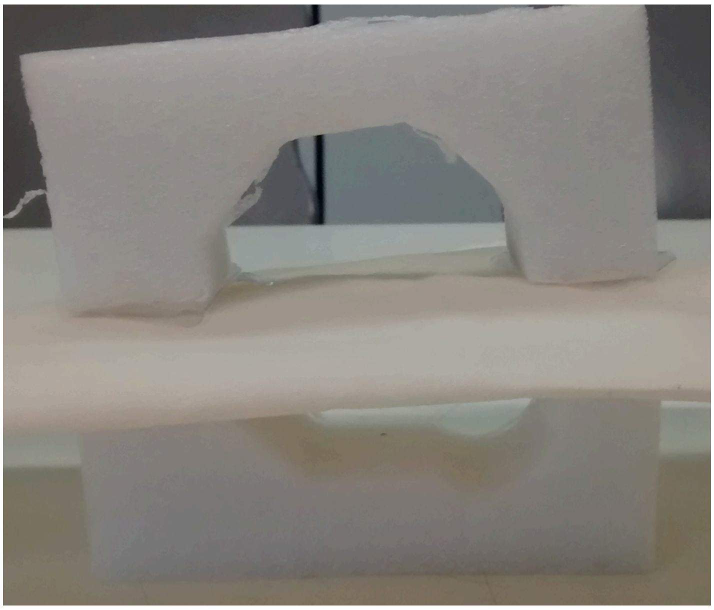

Figure 25 – First version of the form factor of the handles

This quickly revealed itself problematic for one of the fundamental criteria of the rope's form factor: being able to be rolled away when not used. Indeed, the fact that the handles were set up directly in contact with the rope added to their rigidity required to optimize power transmission yielded a problem that wasn't foreseen: the rope couldn't be rolled efficiently anymore. This is demonstrated on Figure 26.

Figure 26 – The early handle model preventing the rope from folding nicely

From there on, a solution needed to be found. After some research, it appeared that changing slightly the prototype by adding "branches" before the handle would solve the problem at minimal cost. Indeed, only a few centimeters of wiring was needed to bring the power from the trunk of the rope to the handles, and the latter could be moved out of the way while rolling the rope. The second version of the handle form factor can be seen on Figure 27, along with a rolled up rope.

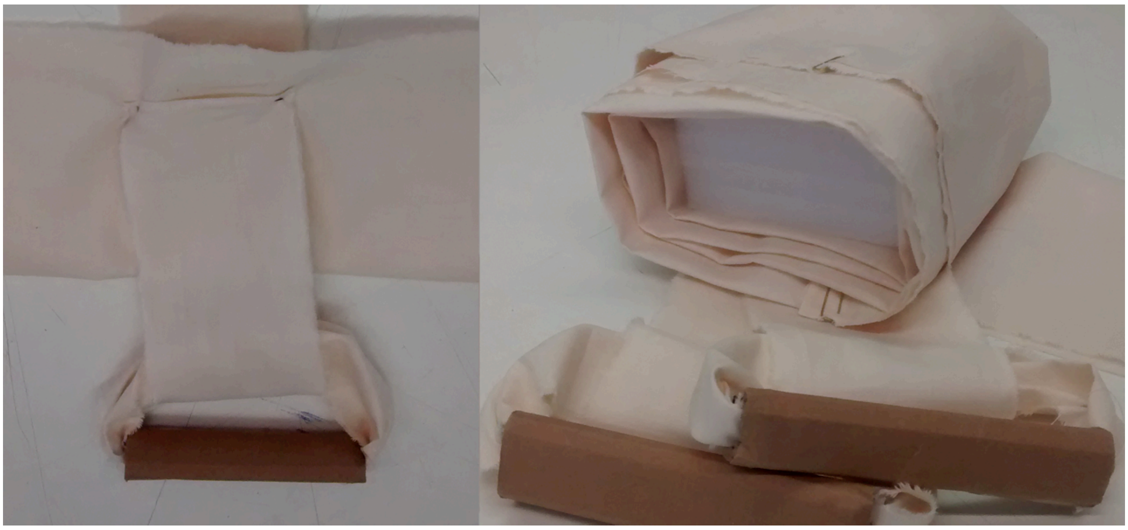

Figure 27 – Second version of the handle form factor, enabling the rope to be rolled

In the end, this form factor was used for the prototype, and conductive thread could be used in the fabric branches of the handle, keeping them very flexible for use.

This process was very significant of the prototyping phase, because unforeseen challenges appeared clearly with practical testing. This required the prototype design to be updated multiple times during the prototyping phase before reaching the final functional version depicted in the next paragraph.

IV.2.b.FINAL PROTOTYPE PRESENTATION

According to the design defined in earlier parts of this study, the proof-of-concept prototype developed during this research is composed of two different parts: a rope and a jacket that connect together when in use.

First, the rope is a few meters long, with a side reserved for the teacher - who can wrap it around his or her waist to keep free hands – and holds the battery pack. In the present case, the battery pack is quite small, since the simplicity of the prototype prevents it from being too energy consuming. On Figure 28, the teacher's side of the prototype is visible, in wrapped position, along with the battery pack and its holder.

Figure 28 – teacher’s side of the rope, with battery pack in its holder

The battery pack lies inside the rope, which is wide open on the picture. It is hold inside an internal pocket preventing it from moving around inside the rope while moving.

The internal wiring is also slightly visible here, as is the thread keeping it in place. Indeed, along the whole rope, the two wires bringing the power to the handles are embedded in a thread holder, as can be seen on Figure 29.

Figure 29 – Internal rope wiring in its thread holder

By fitting all the wiring in tight thread holders, internal movement is prevented, and the wires become coherent to the fabric, making the rope much more steady and providing a better user experience. The next step is to bring the power from these holders to the handles. As indicated in the previous part, this is achieved thanks to small length of conductive thread. The thread is connected to the wire through knots and soldering as illustrated on Figure 30.

Figure 30 – Internal wiring of the fabric between the rope trunk and the handle

Finally, the handles themselves are made using polystyrene in which is embedded the red "leaving detection" LED and on top of which lies an OJAS, the power transmitting component. On Figure 31, the internal wiring of the handle branch is visible on the left, while the finished handle is visible on the right, with the fabric folded.

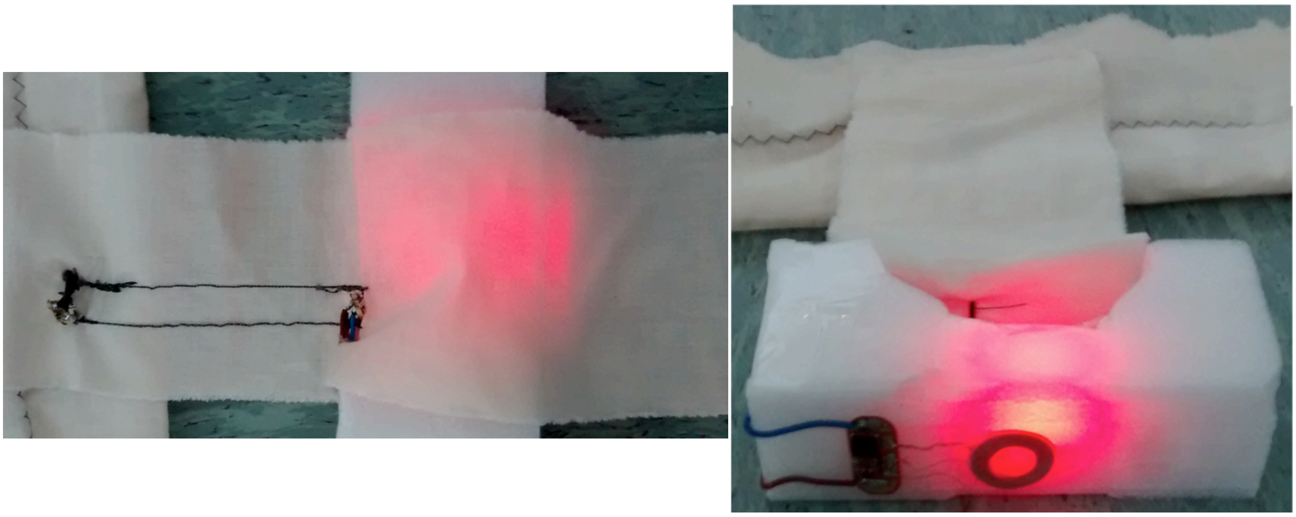

Figure 31 – On the left, a handle with its fabric open to reveal the conductive thread.
On the right, the final handle with the fabric folded, LED inside and OJAS on top.

The second part of the prototype is the jacket. It is composed itself of two main parts. The first one is the glove. In this case, the original design stayed quite similar to the final result of the prototype. It simply consists of a green LED on the backside of the hand, and an OJAS to receive power from the rope on the palm. The inside of the glove can be seen on Figure 32.

Figure 32 – Inside of the prototype's glove.
On the left, the palm view with the OJAS component.
On the right, the back view with the LED facing towards the outside of the glove.

Then, the glove is linked to the jacket and powers it through flexible wires. These wires are going through the sleeve of the prototype, and once again, a thread holder, as seen on Figure 33, keeps them from moving.

Figure 33 – Internal wiring of the jacket's sleeve

Three visibility LEDs are then embedded in the jacket, and wiring is hold tight against the fabric for minimal disturbance of the user. The inside of the jacket is visible on Figure 34. In this prototyping phase, the jacket was black for costs reason, but for actual development, a more visible color would be obviously chosen.

Figure 34 – Internal wiring of the jacket between the three visibility LEDs

The LEDs are facing outwards, and the soldering is hidden by patches of fabric that also protect it and prevent the wearer from being in direct contact with the electronics.

The final jacket has two blue LEDs in the front and one red in the back. It can be seen on the Figure 35, where it is powered directly from a generator.

Figure 35 – Jacket powered on with a generator, front side on the left and back on the right

The final prototype can then be demonstrated in functioning as shown on Figure 36.

Figure 36 – Final prototype in use.
On the left, a handle is visible and not held.
On the right , the handle is grabbed and powers the jackets.

It is important to notice the glove hiding the red "leave detection" LED from the handle and replacing it by its own green LED, following closely the intended behavior.

Finally, an important fact remains as to the flexibility of the prototype. As mentioned previously, it was indeed primordial that the rope stayed flexible enough to be folded efficiently while not in use. On Figure 37, the prototype's rope is displayed rolled up, with the jacket folded by its side.

Figure 37 – Prototype jacket and rope folded and rolled when not used.

V.DISCUSSION

V.1.LEARNINGS FROM THE PROJECT

V.1.a.LEARNINGS FROM THE RESEARCH

The first outcome of this research lies in the situation analysis. After researching in deep details numbers about children endangerment in Finland and reading scientific publications trying to figure out solutions, all the while discussing the issue with first-hand people facing the situation, it appeared clearly that a risk was objectively present in Finland regarding preschoolers' safety. This validated the need for this study in the first place, as exploring solutions using the benefits of the emerging field of wearable technologies could uncover entirely new ways to lower this risk.

Furthermore, and maybe even more relevant to this study was the acknowledged fact that current solutions had obvious shortcomings. Interviewed teachers were fully aware of the existence of the danger for preschoolers, and while obviously trying to lower it as much as possible, recognized that there was a lack of a fully-functional and official solutions.

Current solutions were developed, tried out and improved by the teachers themselves, almost on a case-by-case basis, resulting in tweaked devices more than formally developed and tested safety solutions.

Another consequence of the need for teachers to take the matter in their own hands was the fact that their solutions could difficultly involve new-technologies considering they had to do with available resources and knowledge.

From these considerations, it became completely certain that developing a solution thanks to electronics had a big potential. This solution could then be perfected through a complete design process and tested out in proper settings to assess its performance.

The user testing and efficiency assessment of the concepts developed in this thesis and of the developed prototype are not part of this research due to lack of resources and of the right test settings (this research was carried during the spring and summer, preventing real-life tests in the dark conditions of winter that the solution was intended for). For this reason, these important stages of development are detailed in the next part of this chapter, dealing with potential further steps based on this thesis's results.

Another outcome from this research was learning to deal with problems with very complex constraints. In fact, considering the primary targets were children, it was not possible to analyze and understand the problem thanks to their input. The way to go was thus to focus on the closest actors represented by the teachers. In that sense, the solution had a double target – both with very different interests and goals – as it was intended to be used by children and their teachers. Combining both in understanding the problem and designing the prototype required an important amount of additional preparation (such as taking interest in the children development stage to get an understanding of the situation from their point of view).

Furthermore, as the teachers are not the primary targeted group, the solution had to take into account their constraints as well, such as a lack of available adults for many children, forcing the device to be used almost passively.

However, teachers showed definite interest in a more advanced solution integrating wearable technologies, as they were aware of the room for improvement in the existing situation. They believed integrating technology could ease their job while making the excursions more secure, making themselves more efficient in that task as well. A good example was mentioned with the presence book that could be digitalized and integrated as part of the prototype. Achieving this, accessing information would be easier and it would be possible to get rid of the physical book that teachers are currently required to bring with them at all times.

In that sense, the research brought an interesting experience of real-life design, in a much more complex context than a theoretical case. Filtering through all the available data to figure out the essential factors and how to integrate them in an actual device for a solution as efficient as possible was a very challenging process.

V.1.b.LEARNINGS FROM THE PROTOTYPING PHASE

The prototype is a big outcome of this research as it provides a basis for future improvements and testing, but also enables to list challenges to overcome in the making process.

First of all, the prototyping was a very useful part of the research because it forced a practical adaptation of the concepts yielded by the ideation phase and the discussions with the preschoolers' teachers.

In fact, considering the short timespan and limited resources available for this research, the actual prototyping had two major benefic impacts: understanding and simplifying the concepts to their very core in order to get a minimum viable proof of concept, and highlight unforeseen practical challenges that appeared only through actual tests of the features.

Indeed, even after lengthy discussions and reflecting on how should a solution look like and which feature it should possess, many practical challenges such as the conductive thread resistivity or the handle form factor came up during the process. Having a fully functional – even very basic – prototype validates the theoretical results as far as can be without actual real-life testing.

On that topic, building the prototype is also a first step to these tests, as technical testing could be carried out (such as the OJAS flexibility regarding movement and un-alignment), and user tests can follow up. Finally, having this core prototype stripped down to the very essential is a first brick to an actual product, and a basis to compare to old solutions and more advanced concepts. As mentioned previously, this has not been covered by this research and is thus detailed in the further steps in the next part.

Another major outcome of the prototyping was more on validating the ideation results and thus this whole study's assumptions.

Indeed, while the actual prototype developed was only a proof of concept with very simple and limited features, it still presents a significant improvement over the existing solutions.

As a matter of fact, with a few well-positioned LEDs, it has been possible to address many of the most important challenges uncovered during this research, and provide a viable improvement to the situation.

Firstly, this simple prototype has the distinct advantage of being almost as easy to use as a passive rope, and thus requires no real extra step compared to the existing rope. In that sense, children don't need to change their habits and teachers do not require specific training to use it. Furthermore, even if it embeds some electronics, it doesn't require more attention than a regular rope.

However, the features that were chosen in this final prototype address the three actors at play consistently and efficiently to improve the preschoolers' safety:

There is a system to monitor the critical situation of a child letting go of the rope. While really basic, the warning LED on the handle is very easy to notice, and will provide a good help to the teacher as to make sure that the children stay organized.

Then, children themselves benefit from this prototype as it becomes more interactive and fun than just a rope, which can sometimes feel like a punition. In the present case, holding on to the rope visibly lights LEDs on the child's jacket, giving an additional reason to grab and hold it. Furthermore, seeing all the children around holding on to the rope and being lit up can be a good motivation to do it as well and become part of the group. It was in fact mentioned during an interview that the wish of belonging to the group is a very important factor already for preschoolers, and it is here used in favor of their safety.

Finally, drivers passing by are faced with many LEDs shining from the group of preschoolers, which makes them much more visible in the dark than previously. The visibility problem is here addressed at least partially, and being the major source of traffic accidents with children, it is definitely an improvement over the previous situation.

The outcomes from the prototyping phase are thus three-fold: it forced an efficient synthesis of the theoretical findings, it prepared the field for further steps like tests and improvements, and it validated without doubt the original assumptions of this thesis, even though it stayed a very simple proof-of-concept with little real-life testing.

V.2. FURTHER DEVELOPMENTS

V.2.a. TECHNICAL IMPROVEMENTS

The first and obvious steps that can be taken following this thesis are technical improvements of the prototype. Even if a functional device was implemented which validated the potential for wearable technology in the field of children safety, many compromises have been made along the way, and a lot of shortcomings are currently preventing it from being used in real conditions.

One of the biggest challenges of any wearable deals with waterproofing. In fact, as these devices are meant to be worn like clothes, they need to be washable as well. In the present case, it is especially important that the prototype be waterproof because its intended context of use is during the Finnish winter, when rain and snow are more than commonplace. In the current prototype, nothing has been done related to central requirement, as only the core features have been taken care of in order to validate this thesis's assumptions as fast as possible. However, the rope as well as the jacket uses OJAS devices for powering. As presented earlier, this inherently enables to enclose all the electronic in a waterproof shell, as no access is required for powering.

Furthermore, the rope's battery pack itself can be charged wirelessly using an OJAS, making the waterproofing of the potential very straightforward.

A second technical improvement is linked to the use of conductive thread. As mentioned in the previous chapter, the available thread wasn't fulfilling the requirements to replace traditional wiring in the prototype, forcing the use of classic wiring. This is not a major issue in the prototype and doesn't really prevent real-life use but it still forced to give up on some flexibility for the rope and the jacket, decreasing the seamless user experience. Using ultra-conductive thread instead of all internal wiring would make both the rope and the jacket feel just like normal clothes, and upgrade the user experience to the same as any other jacket.

In fact, one requirement for the jacket is that it replaces other winter clothes ultimately. During the Finnish winter, children already have multiple layers of clothes to put on before going out, and it would be a big improvement and thus reduce the use barrier if the prototype's jacket would come and replace one or more of these layers. Indeed, making sure that the children properly clothe themselves and didn't forget any layer is a primordial but tedious job for the teachers. By making the jacket feel like a normal jacket and making it waterproof, it can now replace the waterproof layer of preschoolers instead of requiring additional clothes which makes the use of the prototype more complicated for the teacher.

The actual product would obviously have reflectors on the jacket and the rope, so that they behave as classic safety jacket on top of their electronic capabilities, and keep being useful even if he power runs out.

Finally, the prototype would need a better overall quality and feel before being a viable device. For now, the material used in its making were as cheap and common as possible, and the look wasn't and sturdiness of the prototype wasn't a concern. This is obviously an important concern for an actual product, and would thus need to be addressed to get a chance of becoming actually useful.

V.2.b. ADDITIONAL FEATURES AND USER TESTING,

After highlighting the purely technical limitations of the current prototype and how to cope with them, the next step is to improve the prototype itself by integrating more complex features. Furthermore, to follow a good design process, user testing would now be a requirement to assess potential improvement from version to version and iteratively update the prototype until it becomes an actual product.

Many concepts have been presented during this research, and most of them seemed as very promising regarding the aim of improving preschoolers safety. However, these are only theoretical assumptions, and even if they are backed by research and discussion with field expert, only proper testing can assess which are truly efficient and how to combine them together.

User testing would actually be the very first step with this thesis' prototype as a first brick towards an actual product. One way to achieve that would be to gather a group of the three main actors in play – children, supervising adults and drivers – and place them in a situation as close to real-life conditions as possible before measuring the differences between old solutions and new concepts. Obviously, simulation is required here, as real-settings are too dangerous to be used for observation.

Both solution efficiency and user friendliness would give important feedback on how to improve the prototype, and each group of actors would probably have different opinions. Improving the prototype with the features presented in this research thus requires an actual research process that would hopefully yield an efficient and functional solution to the problem at hand.

V.2.c.BUSINESS POTENTIAL

Finally, after the prototype has been refined enough to become a viable product, the business aspect is yet to be taken care of.

In fact, it has been already proved here that wearable technologies can improve the situation through different concepts. On top of that, if the prototype is developed all the way to integrate much more complex features, this improvement will definitely become even more significant.

However, this improvement brought to the situation will need to be precisely quantified in order to justify the integration of wearables in official preschooler's safety. If Finnish cities are to provide their preschooler classes with such devices, they will need to be convinced to do so first, as heavy investment would be required.

Solution efficiency and costs would thus be two primary factors to take into account and balance to the current situation. However, none of these were included in the aim of this thesis, and are still needed to actually enable wearable technologies to be used for preschoolers' safety.

A business analysis could thus be beneficial to this end, enabling to identify and estimate all costs, such as mass production and distribution, as well as how to present the potential that was illustrated in this study in a way that can convince public organizations to believe in this improvement.

CONCLUSION

Improving traffic safety is one of the most important priorities in occidental countries, as casualties from accidents are now one of the highest causes of death in all age groups. This research took a particular interest in preschoolers in Finland, and wanted to highlight the potential of an emerging field such as wearable technologies.

In order to do that, the research first took a detailed look at the existing situation, only to confirm the hypothesis that preschoolers were even more vulnerable to accidents than other age groups. Furthermore, the reasons for this vulnerability were uncovered based on previous scientific publications: lack of attention and of cognitive capabilities, small physical size, along with bad visibility conditions were responsible for dangerous settings potentially creating deadly situations.

In a second step, the potential offered by wearable technologies was highlighted: first by presenting the history of wearable technologies and their current state, and then analyzing previous studies which results were significant in the present case.

From there on, this theoretical data was completed by interviews from preschool teachers, enabling a deep and practical understanding of the situation in Finland. Early ideas also emerged from this ideation phase and were refined according to the teachers' expertise.

Many technical improvements for preschoolers' safety were detailed based on wearable technologies. In order to get a functional proof of concept, these concepts were stripped down to their very core, and a very basic prototype was built. It enabled a validation of the created concepts and the actual implementation revealed shortcomings otherwise hidden.

In the end, this prototype showed clearly that wearable technologies had a huge potential for improving preschoolers outdoor safety, as they can address the current pitfalls leading to dangerous situations.

However, user testing will still be required for improving both usability and measuring which of these promising concepts are the most efficient and how to combine them in an actual product.

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